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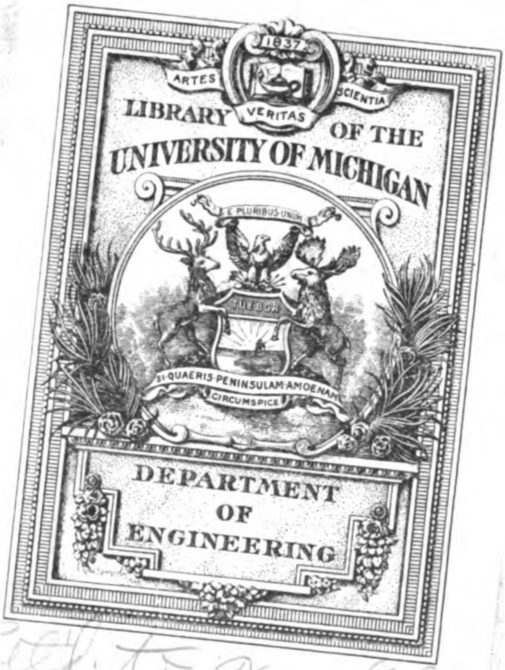

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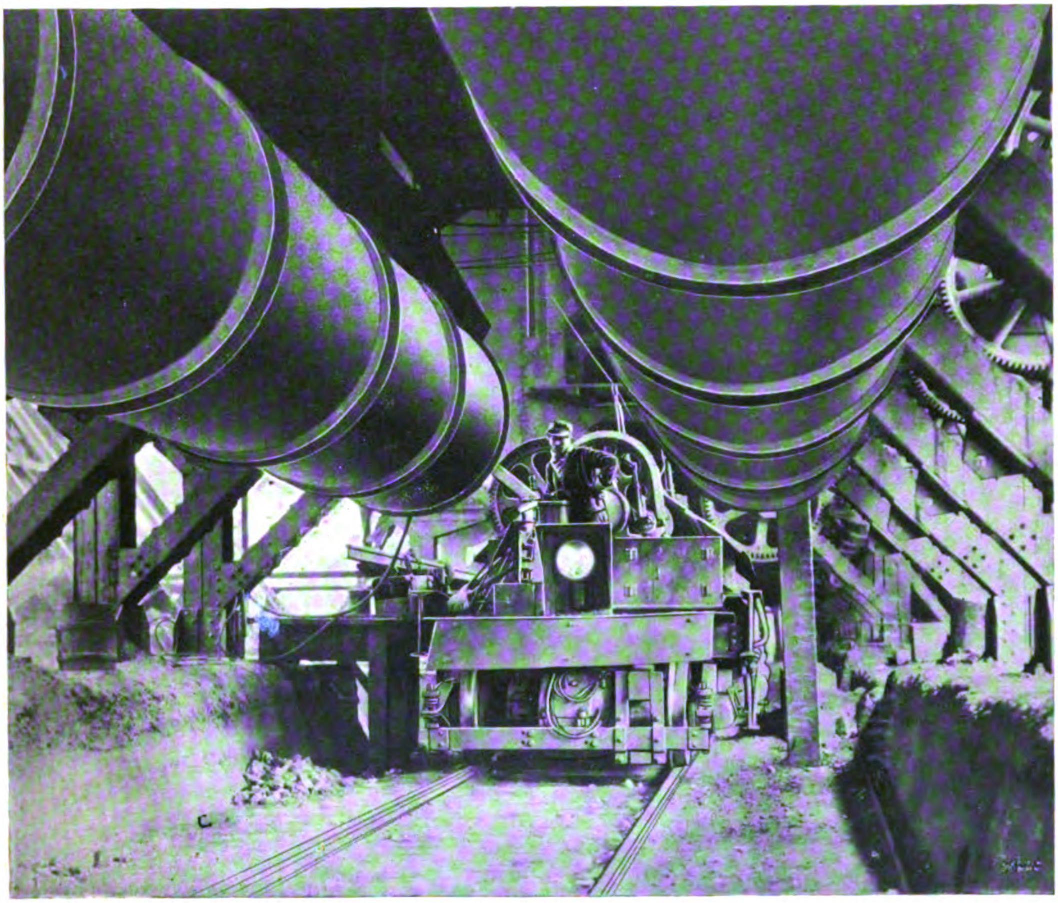
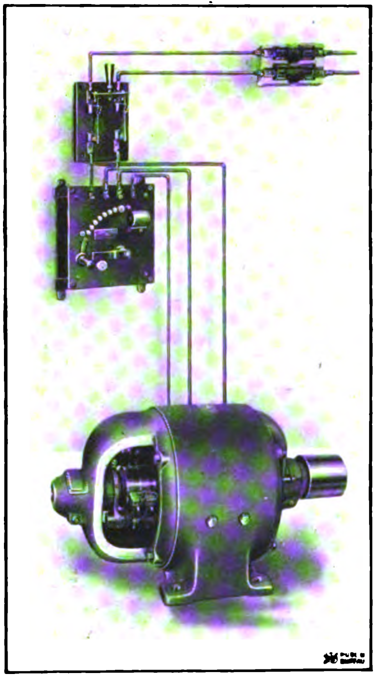


Motor-Driven Scale Car, Operating Under Ore and Limestone Pockets
Illinois Steel Company
(See page 3)

General Electric Company

Motor Starting Equipments

Separate Starting Devices *vs.* Panel Simplicity



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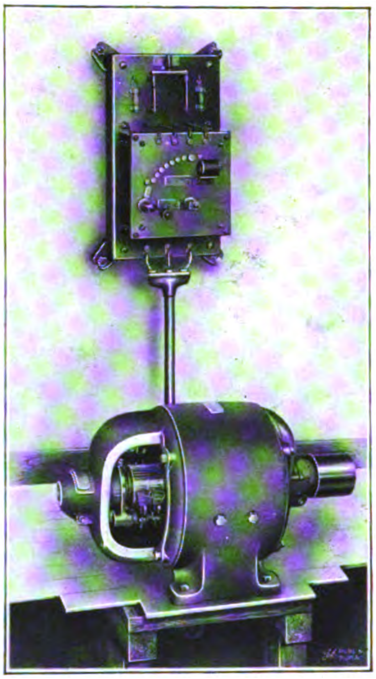

A 10 H.P. MOTOR WITH GENERAL ELECTRIC STANDARD CR 133 (TYPE UP) PANEL

Two Ways of Installing Motor Starting Devices

The Usual Practice

involves greater labor and space for installing and a multiplicity of wiring with possibility of incorrect connection.

The Recommended Way

requires but a single unit, assures proper connection, reduces fire risk to a minimum and makes a neater installation.

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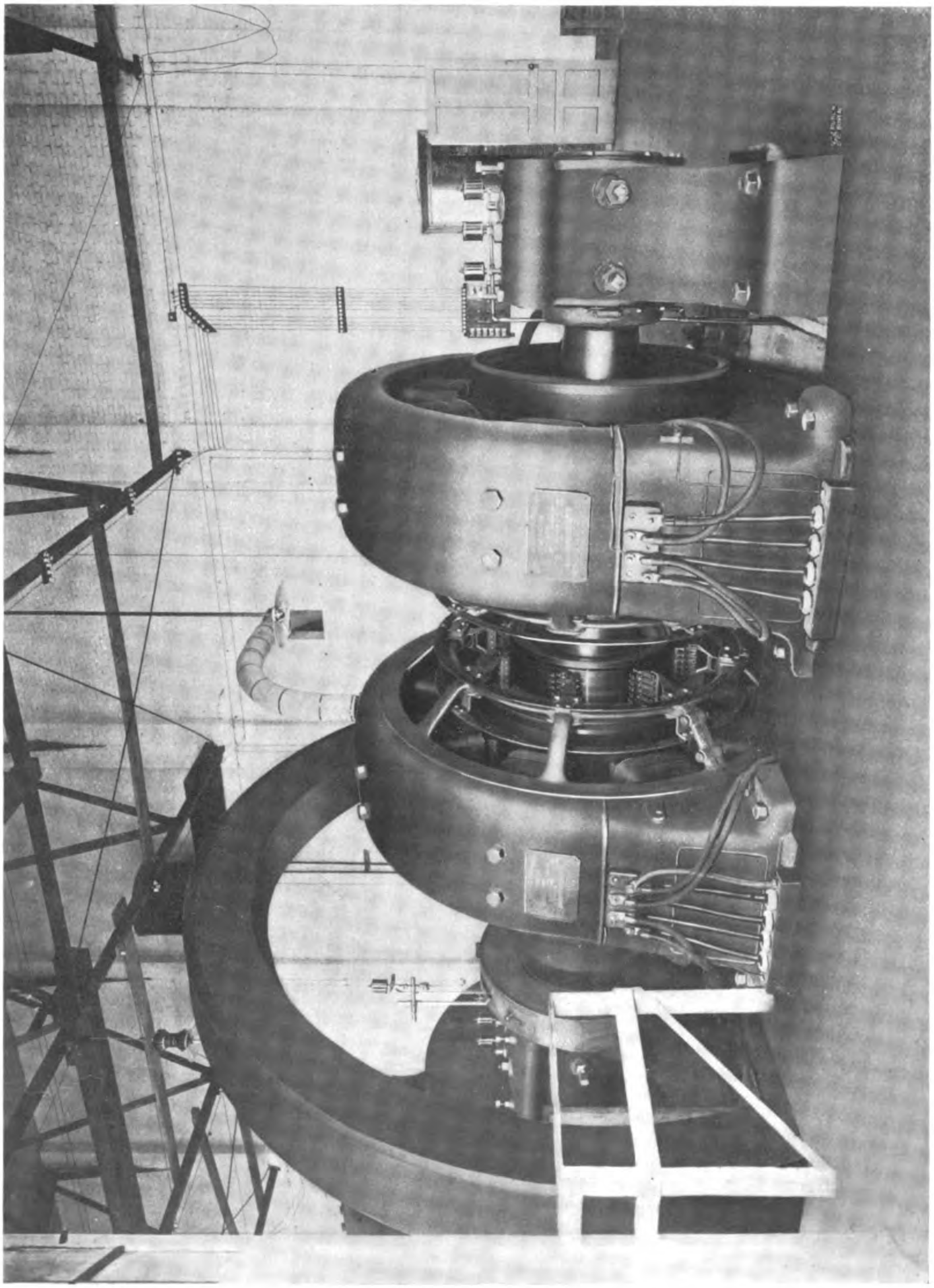

Generators of Indianapolis & Louisville Traction Co., Scottsburg, Ind.

(See page 13)

VOL. X No. 1 SCHENECTADY DECEMBER, 1907

GENERAL ELECTRIC REVIEW

ELECTRICAL MACHINERY IN STEEL MANUFACTURE*

BY W. T. DEAN

The object of this article is to present an outline of the mechanical processes and means of transportation involved in the production of the several forms of commercial steel, without attempting to impart technical information, which would only be of interest to the manufacturer of steel, and would be quite beyond the ability of the writer.

The materials required in the production of pig iron, from which nearly all steel is made, are as follows:

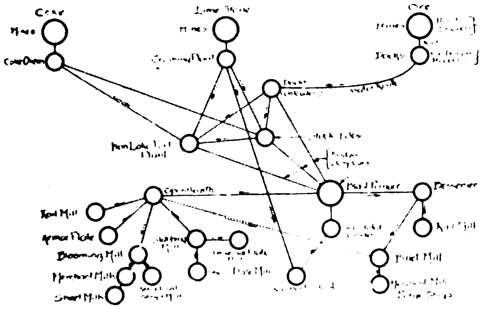

Fig. 1. Diagram of Steel Making Process

First, iron ore, consisting of various oxides of iron of different degrees of purity with respect to the percentages of silicon, manganese, phosphorus, and sulphur contained.

Second, lime stone, which is used as a flux.

Third, coke, which acts as a fuel and as a reducing agent when transformed to carbon monoxide. Theoretically, any form of carbon should serve the above purpose, but in modern blast furnace practice, the great size of the furnaces, with the consequent heavy burdens, require a fuel which combines great resistance to crushing, with a rough structure which will make the entire charge within the furnace as porous as possible. Coke is the only fuel which meets the above requirements.

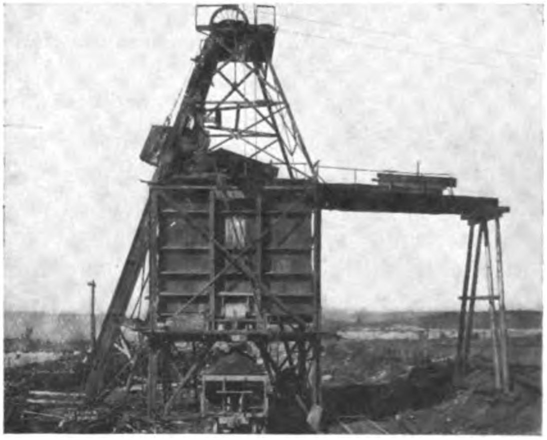

Fig. 2. Shaft House for a deep mine in the Lake Superior region with skip car about to dump and with loaded railway car under the pockets

Figure 1 is a diagram illustrating the entire process of steel making, beginning with the ore, coke and limestone; the transportation agents bringing together the raw material at the blast furnace, thereafter diverting the pig iron to the Bessemer, or to the open hearth process for converting to steel; after

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* Presented before the Schenectady Section, A.I.E.E., October 25, 1907.

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which the raw steel is sent to the various finishing processes.

The principal source of iron ore in this country is the Lake Superior district, and mining is accomplished by open cut working—with steam shovels loading directly into the cars—and by deep mining, usually using the caving system, with narrow gauge dump cars and high speed, powerful hoists; the latter automatically dumping the ore into cars on the ground level. The open cut work is now being done, in at least one mine, by means of towers, cable ways, and motor-operated grab buckets or excavators. For underground transportation both mules and electric locomotives are used.

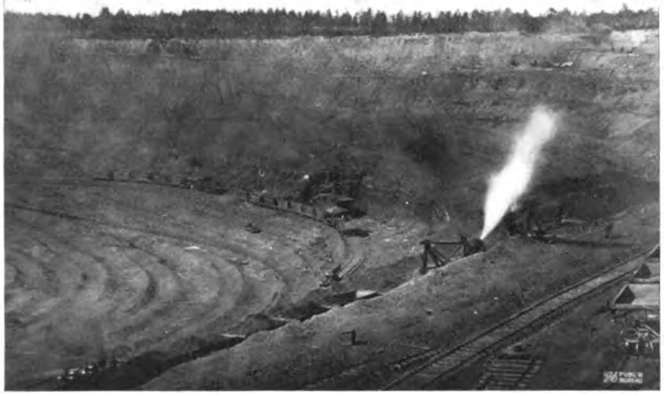

Fig. 3. Open Cut Mining in the Lake Superior District

However mined, the ore must be transported by rail to the loading docks, where the cars are usually run up an incline and dumped into bins, from which the boats are loaded by gravity; it being possible to fully load a ten thousand ton boat in from four to six hours if the bins are full.

From Lake Superior ports the boats must pass through the locks at the Soo—which now pass more tonnage than any other port in the world—and from thence they continue their passage down the lakes, either to Chicago or the Ohio ports, a trip that consumes about four days. By the munificence of Uncle Sam, ample harbors have been provided at South Chicago, so that several boats may anchor in safety within reach of the docks.

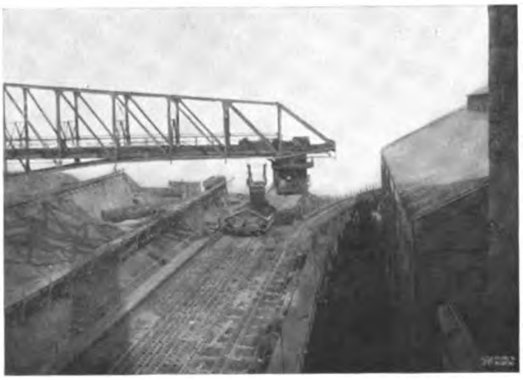

Fig. 4. Ore Bridge with Clam-Shell Grab Discharging Ore into a Transfer Car

Several methods of unloading are in vogue, the motor-operated grab bucket or clam-shell unloader being the fastest device yet developed for the purpose. The original method of unloading involved shoveling the ore into buckets, which were hoisted from the hold by more or less efficient means, and the ore dumped into cars, which were pushed by hand over a structure elevated above the stock piles. Great gangs of laborers from southeastern Europe performed this work a few years ago; now a single operator with a motor-driven unloader displaces one hundred laborers, and five or six operators will unload a ten thousand ton boat in four hours.

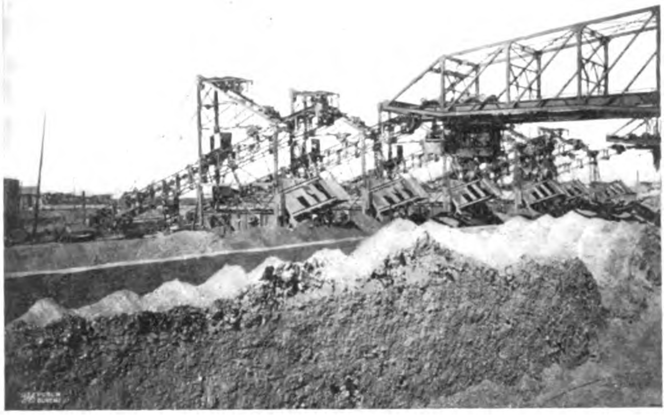

Fig. 5. Ore Bridge and Ore Unloaders

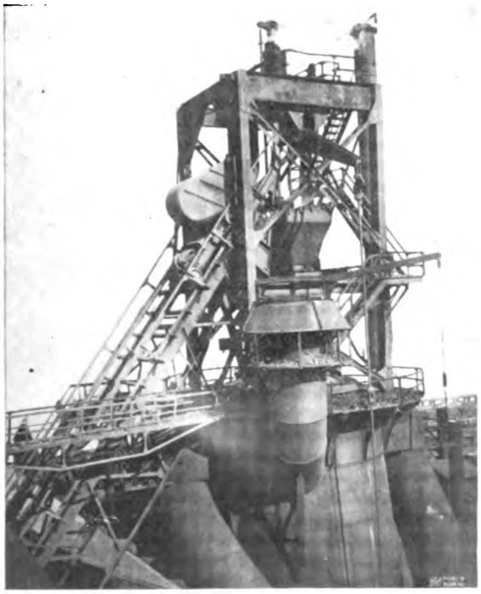

Fig. 6. Top Rigging of Blast Furnace showing a Skip Car about to Dump into the Upper Bell

The unloaders deliver the ore into cars under their own structure, or else into a great concrete trough parallel to the dock, from which the ore bridges remove it to stock piles or directly to pockets supplying the furnaces.

The ore bridge is a steel bridge structure, usually about 600 feet long, mounted on multiple trucks on parallel tracks, and pivoted at both supports; so that, within certain limits, it may take any position across the stock yard. A clam-shell grab, similar to that used on the unloader but of greater capacity, digs and transports the ore. So powerful are the grabs, that six inches of solidly frozen ore offer no obstacle, and the furnaces may be supplied from the stock piles at any season. The grab bucket is operated by means of steel cables and winding drums; the latter receiving their power from motors. Two separately actuated drums are required for each grab, one for the opening lines, and the other for the closing lines; they are used in conjunction with each other, and divide the load when the grab is fully closed and hoisting begins. The grab is opened by holding the opening lines and releasing the closing lines, the lines being held by means of dynamic and solenoid brakes, or air brakes.

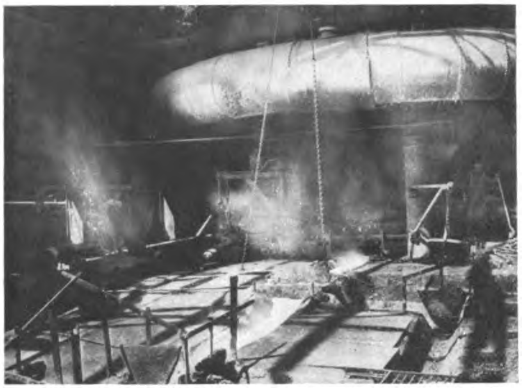

Fig. 7. Base of Blast Furnace During the Cast

Taking the ore from the trough at the dock, or from the stock piles, the ore bridge deposits it into hopper-bottom bins, or into hopper-bottom transfer cars on top of the bins.

Similar bins are supplied with coke and limestone from cars, and the proper mixture of ores, together with suitable proportions of coke and limestone, are withdrawn from the bottom of the bins and weighed; hopper-bottom scale cars being used in weighing the charge, and accurate records kept by means of tape printing devices.

The scale cars are motor-operated, and run on standard gauge tracks, which pass over pits into which the buckets or skip hoist cars descend at an angle to clear the tracks. The whole scheme of ore handling may be readily seen from the illustration.

The top of a typical blast furnace of the largest size—the nominal capacity of which is six hundred tons of pig iron in twenty-four hours—is shown in Figure 6, and the bottom is illustrated in Figure 7.

The charge is hoisted and dumped automatically by motor-driven hoists, adjusted so accurately that the position of the cars, when at the top or bottom, never varies more than six inches. All parts of the hoisting machinery are made as strong as possible to prevent the possibility of delays; and spare motors, controller parts, gears, etc., are kept constantly on hand, for the success of a blast furnace depends very largely upon the absolute regularity of all its functions.

Without going into the chemistry of the complicated reactions taking place in the interior of a blast furnace, it may be said in general that the combination of fuel, flux, ore, and heated air under pressure, produces pig iron, slag, and combustible gas.

The pig iron is tapped out at intervals of four hours through an orifice near the bottom of the hearth, while the slag is tapped out as often as is necessary through the "cinder notch," which is located some four feet higher than the iron tapping hole. The gas flows continuously, and is used in part to heat the stoves, the excess being burned under boilers to produce steam, used in internal combustion engines, or allowed to escape into the atmosphere.

The molten pig iron is transferred in special ladle cars to the Bessemer or open hearth departments, as the case may be, while the slag is hauled away in molten form in "cinder pots," or is granulated, by means of water, for the manufacture of cement.

Bessemer Process

The Bessemer process is too well known to need extensive description. The pig iron, still molten from the blast furnace, is poured into a large cauldron or "mixer," where the product of several furnaces may be mingled and averaged; still molten it is transferred in quantities of about fifteen tons to the Bessemer converter, the pig iron being poured into the top of the converter, which is partially tipped downwards for the purpose; air blast is then turned on and the vessel turned upright.

After being "blown" for the required length of time (as judged by the color of the flame, which varies from dark orange to white), the vessel is partially turned down, the blast shut off, and spiegel-eisen added.

The length of the "blow" varies from seven to fifteen minutes, depending largely upon the amount of silicon in the pig iron. The blowing process reduces the pig iron to nearly pure iron, the spiegel-eisen is added to bring the carbon and manganese contents to the specified figure.

After the addition of spiegel-eisen, the vessel is immediately turned down and the contents poured into a waiting ladle, from whence it is poured into cast-iron molds, on small flat cars called "turtle backs." The steel chills upon contact with the molds, and the latter are strpiped off within from five to ten minutes after casting, leaving the ingots, as the steel is now called, red hot and solid on the exterior but still soft, or even molten, within.

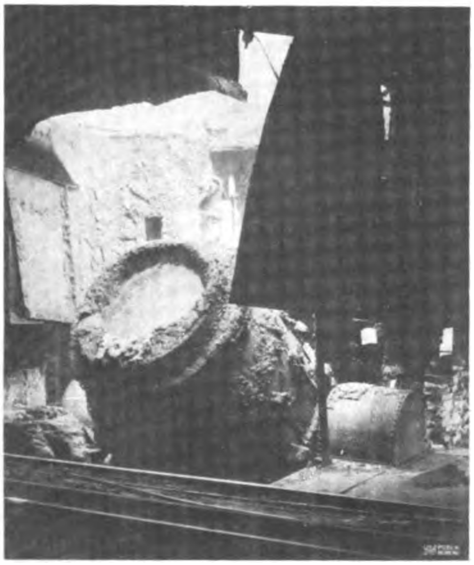

Fig. 8. Bessemer Converter

The ingots are now quickly transferred to the rail mill reheating furnaces, or to the "soaking pits," where a high homogenous temperature throughout the ingot is obtained in less than two hours. They are then drawn by electric ingot cranes, and are transferred over motor-driven tables to the blooming mill, where the first reduction in section is made. From three to seven passes are made in the blooming mill and the product is called blooms.

The blooms are then sheared into lengths which will produce from two to four rails of the weight desired, and about 15 per cent. of the end of the bloom goes into scrap, in order to reduce the percentage of defective rails, as this portion of the bloom is the part most likely to be lacking in homogeneity.

The sheared blooms pass through some fifteen stands of rolls, being gradually reduced in section and elongated until the finished shape is attained, when hot-saws cut them into commercial lengths.

The entire time from ingot to finished rail is about 90 seconds, and an ingot is bloomed every 35 seconds. When sawed to length the rails are still at a bright red heat, and they must be allowed to lie on the cooling beds some time before being straightened, drilled, and shipped.

Open Hearth Process

As pointed out previously, the Bessemer converter requires about ten minutes to produce fifteen tons of steel. The open hearth process handles larger quantities of metal but is a much slower operation, a complete reaction requiring about eleven hours. As a consequence, the open hearth process is costly; on the other hand it is certain of results, and many ores not suitable for the Bessemer process may be used. The demands of the railroads for better rails, and the increasing scarcity of Bessemer ores, are rapidly retiring the Bessemer process. In fact, no Bessemer plants are under construction or are contemplated at the present time.

The open hearth furnace is a large, shallow vessel, in which approximately equal portions of pig iron and cold scrap steel are melted by means of a gas flame. Suitable fluxes are added as required, forming a protecting

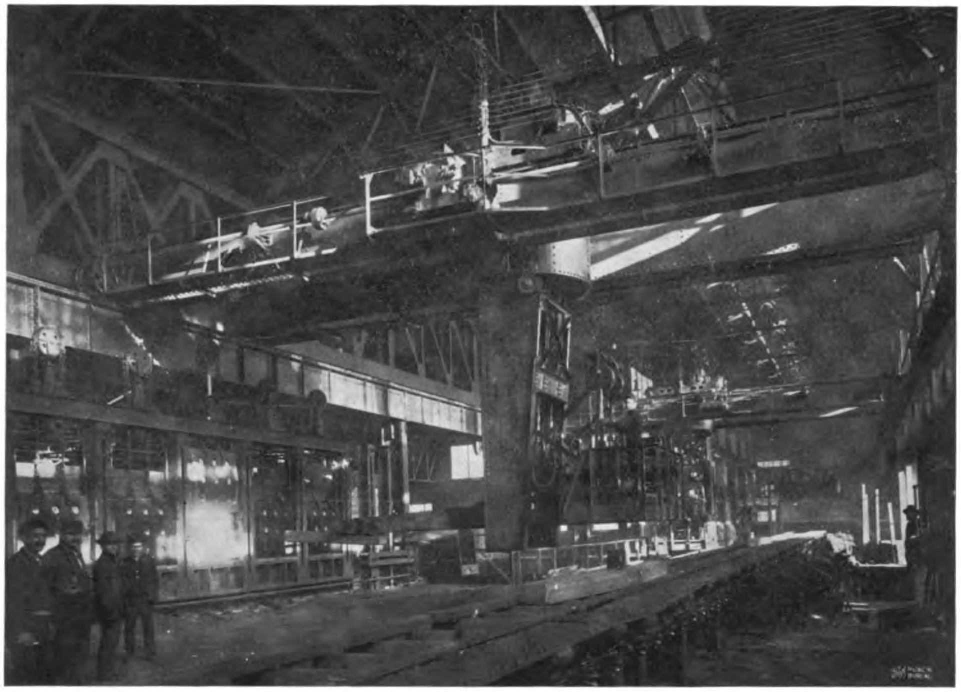

Fig. 9. Reheating Department of the Structural Shape Mill showing Overhead Charging Cranes

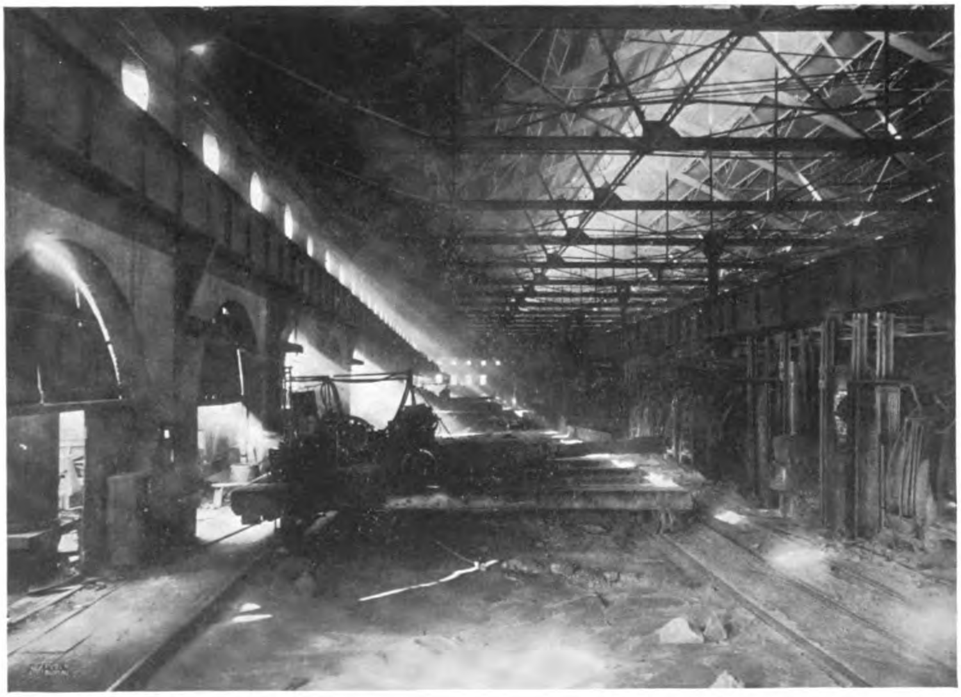

Fig. 10. Charging Side of Open Hearth Plant showing Motor-Operated Charging Machine

coating over the top of the bath. The temperatures attained are so high that the steel boils violently. Samples are taken at intervals, and the furnace is tapped when the desired analyses are obtained.

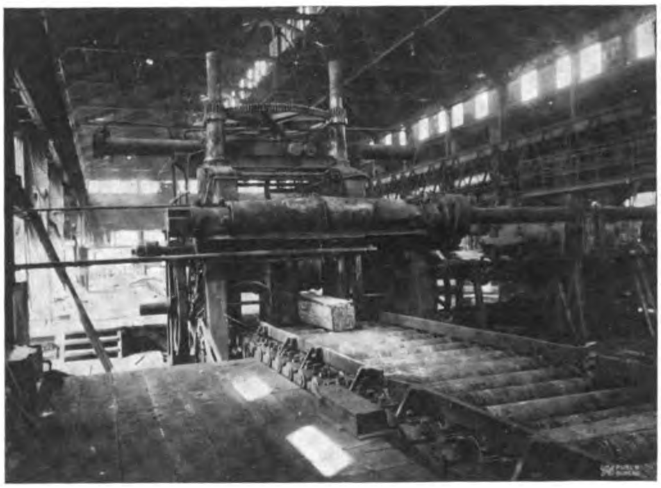

Fig. 11. A Close View of a 40 in. Slabbing Mill showing Vertical and Horizontal Rolls

All of the molten metal, as well as the cold scrap about an open hearth plant, is handled by means of motor-driven machines; such as charging cars and pit cranes. The pit cranes are usually of about one hundred tons capacity, as the entire cast of a furnace, weighing sixty tons or more, must be tapped at one time and into one large ladle suspended from the crane. From the ladle the steel is tapped into ingot moulds, as in the Bessemer process.

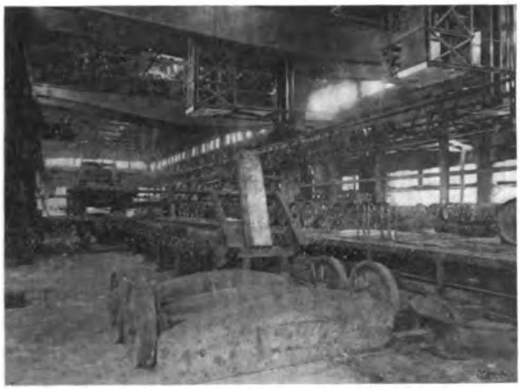

Fig. 12. A 40 in. Slabbing Mill showing overhead charging and drawing cranes, motor-operated tables and mill in background

In addition to operating the charging cars, cranes, rail mill, etc., motors are used to drive the various other mills, *viz.*, the slabbing, shear plate, blooming, and structural mills. The first of these, *i. e.*, the slabbing mill, is a form of blooming mill equipped with vertical as well as horizontal rolls and produces slabs of suitable thickness and width for further rolling in a shear plate mill or a universal plate mill.

A shear plate mill may be defined as a mill for rolling plates to a definite thickness, without particular regard to width. Such a mill is not provided with vertical rolls, and the product is sheared on both sides and ends to the required shape.

Finished sheared plates are handled about the mill and on the loading docks by electromagnets attached to traveling cranes.

The blooming mill, when alone, is used to convert ingots into blooms for some subsequent process, and it is frequently used to produce various sized commercial billets as well. The processes are similar to those described when discussing the rail mill.

Blooming mills, when engine-driven, are usually "two high," *i.e.*, have two rolls, and are reversed for each pass. When motors are applied to the driving of such mills, it has been thought best to build the mills "three high," or with three rolls running continuously in one direction, the piece passing first between the middle and lower roll, returning between the middle and upper roll.

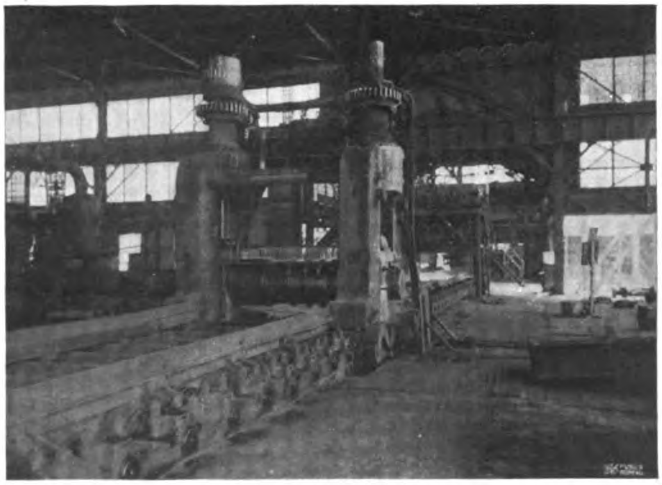

Fig. 13. A 40 in. Blooming Mill with Motor-Driven Screw Down Motion

Blooms for subsequent rolling into channel and I beams are rolled into a shape roughly approximating the letter I, then reheated and transferred to a structural shape mill.

The structural shape mill differs from the rail mill only in that the several passes are usually made through several roll stands, driven by a single engine; thus necessitating frequent returns over practically the same space. This requires special machinery for transferring the piece from one pass to another; a duty performed by motor-driven traveling tilting tables. The machine consists of a roller table with its driving motors, the whole mounted on motor-driven trucks so as to pass along in front of the several roll stands. The table must also tilt up and down, in order to reach the upper and lower passes of a "three high" mill.

As the piece becomes elongated, means must be provided to support and move the portion which would otherwise overhang the table. For this purpose traveling roller tables are provided behind those just described. The operator—who rides on the front or traveling, tilting table—must be

Fig. 14. Pit of Drawing Side of Open Hearth plant showing 100 Ton Overhead Ladle Cranes

able to control, almost simultaneously, ten distinct motions, as well as watch the piece of steel. I have explained the above at length in order to show the importance of supplying strictly reliable and easily operated automatic controllers for such work.

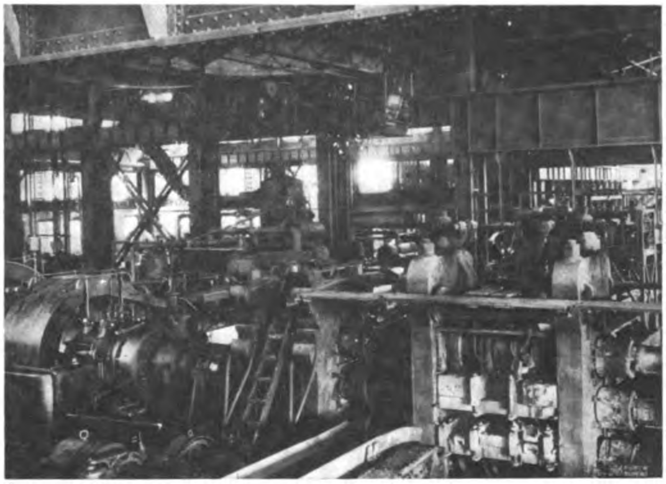

Fig. 15. A 24 in. Structural Shape Mill with Motor-Operated Traveling Tilting Tables

Cement Plant

When discussing the blast furnace, the granulating of the slag was mentioned. The slag, or cinder, as it is more commonly called, is allowed to run from the furnace in open channels towards concrete tanks. About ten feet from the end of the run, water is forced at a pressure of 20 pounds into the bottom of the run, and mingles with the stream of molten cinder. The result is a buff colored, light weight, granular substance, known as granulated slag, which is dug out of the tank with motor-driven, clam-shell grabs, and loaded into cars for transfer to the cement plant.

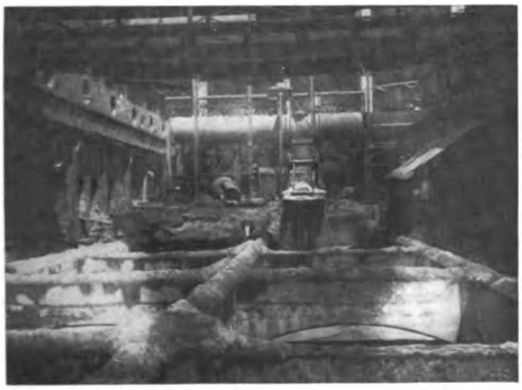

Fig. 16. Concrete tank for granulating cinder with clam-shell grab bucket operated from overhead traveling crane

Approximately 55 per cent. of crushed limestone is added during the process of cement making, and the mixture is finely divided in tube mills, calcined, and again finely divided in ball and tube mills; making an excellent Portland cement known as the Universal brand.

All of the machinery in the plant of the Universal Portland Cement Co. is motor-driven; an article describing this plant and its equipment was published in the November issue of the Review. The power is supplied from the Illinois Steel Company's plant at South Chicago, distant ten miles, and as it is largely obtained from waste blast furnace gas, its cost is surprisingly low. Approximately 9000 kw. is transmitted to the cement company at 22000 volts, and the output of the cement plant is about 10500 barrels per twenty-four hours.

When a stranger visits the works of the General Electric Company at Schenectady, he is astonished at the splendid provision for every form of manufacturing, and wonders who can grasp the details of so complicated and yet so perfect an enterprise; but the stranger visiting a great steel plant is lost in awe at the Titantic forces made to do man's bidding at the touch of a finger, and trembles at the rumblings of the volcanoes in leash, spouting white hot iron and molten steel.

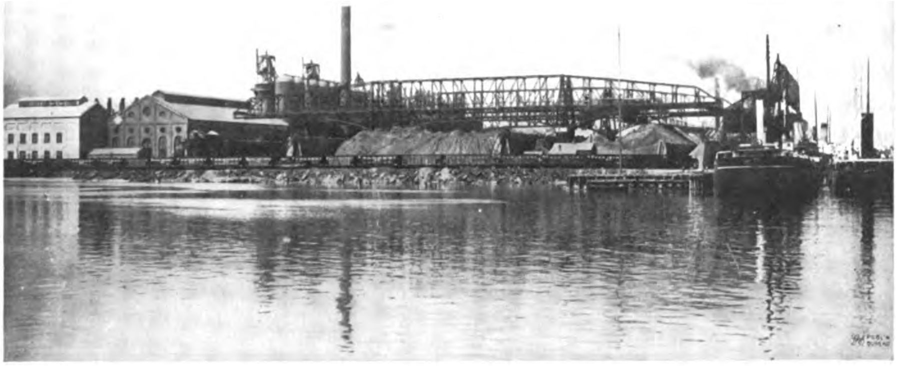

Fig. 17. General view of North Slip, Illinois Steel Company, South Chicago Illinois, showing steamers, ore unloaders, ore bridges and transfer cars and furnaces in the background

THE HIGH TENSION D. C. LINE OF THE INDIANAPOLIS AND LOUISVILLE TRACTION COMPANY

By John R. Hewett

In the issue of the "Street Railway Journal" for September 7, 1907, there was a reprint of a paper read before the Chicago section of the American Institute of Electrical Engineers on March 26th by Mr. W. J. Davis, Jr., which paper contained the very interesting table given below:

600 VOLTS DIRECT CURRENT	LENGTH OF TRACK	NO. OF CARS	SIZE MOTORS	TOTAL MOTOR H.P.
Texas Traction Co.	63 miles	15	4 x 75 h.p.	4,500
Elmira, Corning & Waverly	15 "	7	4 x 60 "	1,680
Buffalo, Lockport & Rochester	70 "	19	4 x 75 "	5,700
Oregon Railway	40 "	8	4 x 75 "	2,400
	188 miles	49		14,280
1200 VOLTS DIRECT CURRENT				
Central California Traction Co.	16 miles	6	4 x 75 h.p.	1,800
Pittsburg, Harmony, New Castle & Butler	63 "	12	4 x 75 "	3,600
Indianapolis & Louisville	41 "	10	4 x 75 "	3,000
Indianapolis, Columbus & Southern	. . "	3	4 x 75 "	900
San Jose & Santa Clara	9 "	8	4 x 75 "	2,400
	129 miles	39		11,700
SINGLE-PHASE 3300 or 6600 VOLTS				
Washington, Baltimore & Annapolis	52 miles	25	4 x 125 h.p. 2 x 125 "	11,500
Central Illinois Construction Company	40 "	10	4 x 75 "	3,000
Anderson (S. C.) Railway	35 "	3	4 x 75 "	900
Richmond & Chesapeake	15 "	4	4 x 125 "	2,000
	142 miles	42		17,400

Total horse-power in motors sold 43,380, of which
1,200 volt direct current has 27 per cent.
600 volt direct current has 33 per cent.
Single-phase alternating current has 40 per cent.

This table shows the horse-power, motor capacity, number of cars and length of track of the various high speed interurban roads for which the General Electric Company has recently taken orders; and the point of prime interest is to be found in the fact that fully two-thirds of the total motor capacity sold consists of 1,200 volts direct current and single-phase alternating current motors, which is a plain evidence that there is an earnest movement on foot in the engineering world to reduce the first cost of constructing roads by the application of higher working voltages.

A careful study of the above table will be instructive as showing what confidence is now being placed in what may be styled the "New Systems."

The lines of the Indianapolis & Louisville Traction Company are the first to be put into operation with the trolley pressure of 1200 volts D. C., and for this reason an additional interest will be attracted to that system. As the name implies, the company will operate their cars from Indianapolis to Louisville, although their right of way only extends from Seymour to Sellersburg. Very favorable agreements have been entered into with the Indianapolis, Columbus & Southern Traction Company, the Louisville Northern Railway & Light Company and the Louisville & Southern Indiana Traction Company, which are the roads to bridge the intervening distance not covered by the Indianapolis and Louisville lines.

The car barns and power house of the Indianapolis & Louisville Traction Company are erected at Scottsburg, Indiana, and both are substantial red brick buildings. The power house contains two horizontal single cylinder Corliss engines rated at 750 horse-power each, coupled to four General Electric MP-8-300-120-600 volts compound wound generators. Two generators are mounted on the extended shaft of each engine, and the windings are connected in series in order to be additive and to give 1,200 volts. The fields are also connected in series on the grounded side. The boiler equipment consists of four Babcock & Wilcox water tube boilers, each rated at 300 horse-power and working at a steam pressure of 160 pounds per square inch. The switchboard consists of two generator panels, two feeder panels and two equalizer panels, all of which were supplied by the General Electric Company.

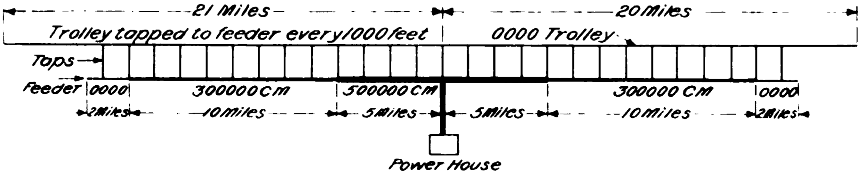

Fig. 1. Diagram Showing Arrangement of Feeders

The car barn is 173 ft. 4 in. long and 69 ft. 10 in. broad. It is provided with four parallel tracks and four wheel pits each 55 feet in length, and has more than sufficient capacity for holding the present equipment, which consists of eight 50-foot passenger cars and two express cars. One end of the car barn is fitted up as a work shop, being equipped with lathes, drills, forges and other appliances which are sufficient, not only to maintain the cars when once in operation, but to do all the work incident to installing the electrical equipment in the first place. The offices of the master mechanic, train dispatcher and secretary and treasurer of the line are also under the same roof as the car barn.

The length of the road at present in operation is a little over 40 miles, and the most noticeable feature of the line construction throughout is that it differs in no single respect from a well equipped 600 volt D. C. road. The trolley, which is of 0000 capacity, is supported by a bracket construction and the feeders are arranged as shown in Figure 1.

It will be noticed that the power house is situated in a central position and that the feeders extend for a distance of approximately twenty miles in each direction. It is possible to operate the road for its entire length at 600 volts pressure, but as will be anticipated, under such condition the voltage is poor at both ends of the line.

The road bed is rock ballasted throughout and the grading is finished in a style seldom equalled on any new interurban system. It is very possible that exceedingly good schedule speeds will be maintained between Indianapolis and Louisville. The two largest bridges on the road are respectively 525 and 480 feet in length, the former crossing the Muscatatuck River and the latter the Vernon Fork of the same.

The greatest interest will undoubtedly be centered in the electrical equipment of the cars, as the arrangements are such as to permit their operating on both 600 and 1,200 volts D. C. Each car is equipped with four GE 205 motors, which are commutating pole machines and have a capacity of 75 horse-power each. These motors are connected in two pairs, each pair consisting of two motors in series, so that the voltage across the terminals of each individually never exceeds 600. The fields and armatures are provided with extra insulation as a safeguard against any momentarily high values of voltage should any pair of wheels skid or slip during operation. Extra large creepage surfaces are provided owing to the fact that there is 1,200 volts between the brushes and the ground. The Sprague General Electric multiple unit Type M automatic control is used. The control circuits proper are operated by current at 600 volts, the high tension of the trolley being reduced or transformed by means of a dynamotor. This dynamotor works on the same principle as the auto-transformer, or perhaps it may be more clearly described as a motor-generator with both windings wound on the same core and in the same slots. It is provided with a commutator at each end. The 600 volts for operating control circuit when the car is running on 1,200 volts is obtained by the dynamotor as follows:

The trolley is connected to one set of brushes on the first commutator, the other set of brushes on commutator No. 1 being connected to a set of brushes on commutator No. 2, while the remaining set of brushes on commutator No. 2 are grounded. As one set of windings is always generating while the other set is motoring, it is obvious that the potential across the brushes of commutator No. 2 will be half of the applied voltage, namely 600 volts. The 600 volt current obtained in this manner is not only used to energize the contactor coils, but also to operate all the auxiliaries. The dynamotor has a rated capacity of 12 kw.

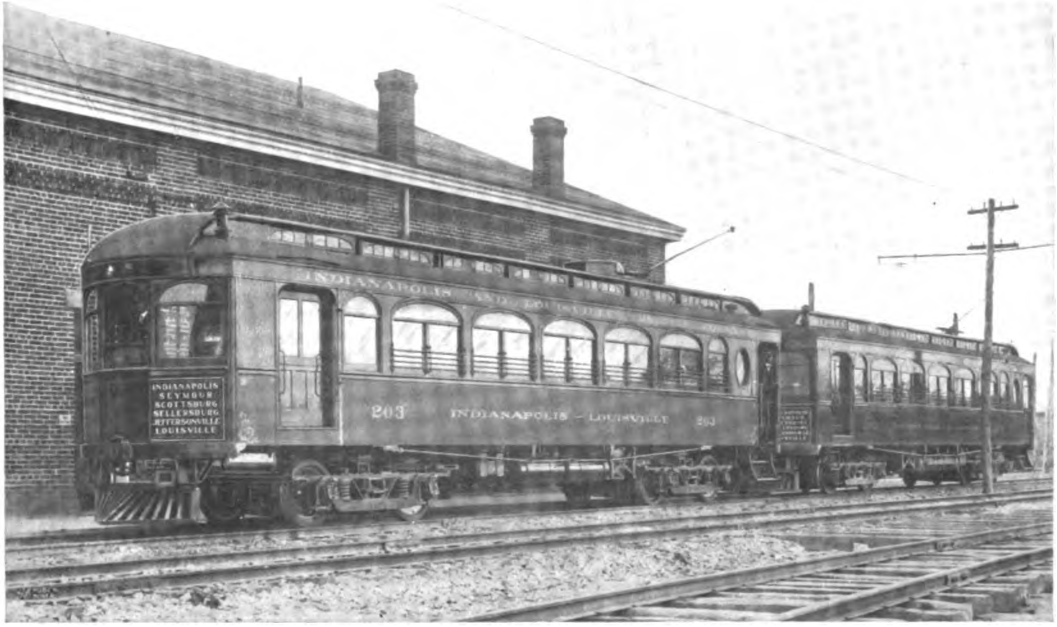

Fig. 2. Two-car train of the Indianapolis & Louisville Traction Co.

The contactor fingers make and break the motor circuit current when operating on both 600 and 1,200 volts, and for this reason they are designed with additional insulation.

As stated previously, the motors are provided with commutating poles, and as this is the first instance of a D. C. commutating pole railway motor being placed in service to operate at 1,200 volts, the most essential features may be of interest. The exterior of the motor, as shown in Fig. 3 is of the box frame type, and in general the construction is similar to that of the Standard General Electric Railway Motor of the same rating, with the addition of commutating poles.

The commutating poles are situated midway between the exciting poles and have their windings all connected in series with one another and with the armature. The function of these commutating poles and their operation may best be understood by considering an imaginary view of the armature with two poles developed to form a flat surface. In such a diagram there will be a broad sheet of current flowing in the armature in the direction of the motor shaft under one pole, and in the reverse direction under the other pole. This sheet or band of current produces a magnetic field of its own which is opposed to the main flux of the field poles and changes the distribution of this main exciting flux. Not to enter too much into detail, the principal effect of this distortion may be stated as the formation of a strong magnetic field midway between the N. and S. pole of the motor, which field has the harmful effect of producing a local current in the armature conductors at the very instant when their current is being commutated and reversed by passing from the influence of one field to that of another. Or, in other words, the magnetizing effect of the armature is at its maximum value midway between the poles, and it is the cutting of this field that produces a local voltage and causes sparking at the commutator. The function of the commutating pole is to produce a field of equal strength and in an opposite direction to this magnetizing force produced midway between the exciting poles, and thus to counteract or wipe out the magnetic field which causes local currents at the point of commutation, and consequently to eliminate sparking.

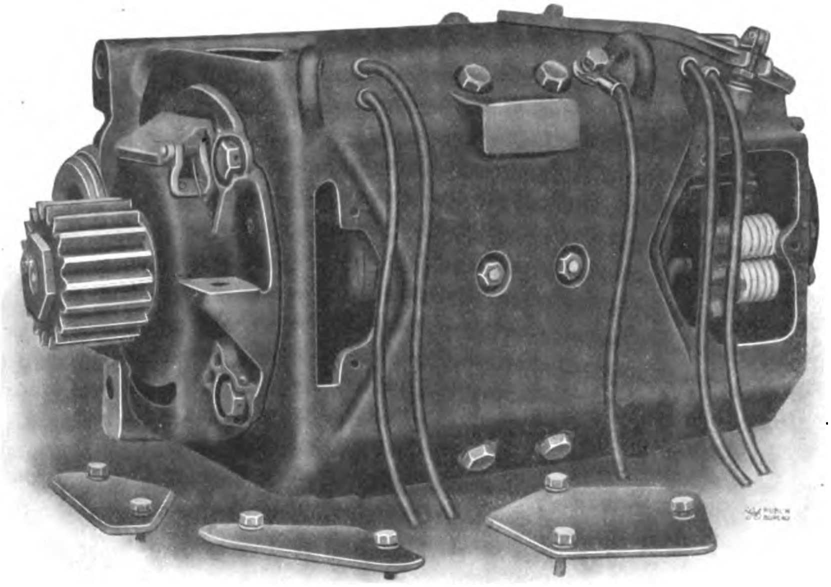

Fig. 3. GE-205 Commutating Pole Railway Motor

The fact that the commutating poles are connected in series with the armature insures their magnetic strength varying in accordance with the strength of the armature current when operating on fluctuating loads. There are other minor factors which enter into this consideration, but the above will show the fundamental principles.

The practical benefits derived by the use of commutating motors may be summarized as follows. With the elimination of sparking the etching of the commutating bars will be materially reduced, and as the carbon brushes are required to carry only the line current and no local current, they will wear better and disintegration will be materially reduced. The outcome of this will be that the commutator bars will wear less rapidly and there will not be so much high mica to be worn down, with the result that a car will be able to make a greater number of car miles before its being necessary to send it to the car barn for repairs.

The lack of sparking will further permit the use of higher voltages between commutator bars and consequently greater trolley voltages, which means that it is now practical to operate a D. C. road of 1,200 volts for double the distance between sub-stations. The application of commutating poles is by no means limited to the 1,200 volt motor; the General Electric Company are now manufacturing a complete line of commutating pole motors to operate on 600 volt circuits.

The following table will give some idea of the elasticity of a combined 600-1,200 volt system, and it is worthy of mention that the range of speed can be still further increased if the requisite commutating switches are provided.

Fig. 4. Power House of the Indianapolis & Louisville Traction Co.

VOLTAGE AT MOTOR TERMINALS	TROLLEY VOLTAGE	VOLTAGE OBTAINED WITH	SPEED OF CAR	CLASS OF SERVICE
600	600	Motors in parallel	40 miles per hr.	Suburban and Interurban
300	600	2 Motors in series	20 miles per hr.	City service
600	1,200	2 Motors in series	40 miles per hr.	Suburban and Interurban
300	1,200	4 Motors in series	20 miles per hr.	Suburban and City

TWENTY-FIVE YEARS OF INSTITUTE HISTORY

By T. C. Martin

In view of the fact that according to the printed records of the Institute, the first steps towards its formation were taken in April, 1884, it may seem premature for me to-night to talk even twenty-five minutes about twenty-five years. But we are on the verge of 1908, and the Institute was already in existence in the minds of its advocates and friends in 1883, long before we circulated for signature the "call to arms" now hanging on the walls of the headquarters in the beautiful new home on Thirty-ninth Street, New York. I had the honor to assist Dr. N. S. Keith in the preparation of the famous April circular and to secure many of the notable signatures to it. It fell equally to my lot to prepare and issue the first volume of transactions and to make the first secretarial report. I have never enjoyed the confidence of the Institute sufficiently to be trusted as its treasurer, but I have been elected to every other office in its gift and may therefore venture to discuss it, on your invitation, from the inside and its various other respects. A good many of us in the electrical field—over 5000 now in membership—are interested in the Institute's welfare, and to us the story of its trials and struggles and evolution is not altogether vain and insipid. History repeats itself, and probably the growth of every engineering and scientific society follows much the same course. We electrical engineers came pretty late in the procession, but after all are not in a class by ourselves. Scientific and engineering bodies are ancient rather than modern inventions. A young mother whose infant was ailing went to an old-fashioned doctor and asked for treatment. He prescribed castor oil. "But doctor," she exclaimed, "castor oil is such an old-fashioned remedy." "Madam," replied the doctor drily, "babies are such old-fashioned things."

No one will deny to the Institute, however, characteristics and idiosyncrasies due to the circumstances of its birth and to the development of the mighty agencies included under the generic name of electricity. There may be, and I trust there is, something personal in the feeling that the makeup of the Institute has a youthfulness and vivacity about it that the other kindred societies do not all possess. I was only thirty myself when elected to the presidency, and while some of my successors, down to this very year, have been dangerously near that age I am told that in other societies such juvenility in high office would be regarded as scandalous. It seems likely that amongst the Electrical Engineers, youth will not yet be a bar to the supreme dignities. A notable orator in speaking about the late Mr. James G. Blaine, said that his magnetism had to be taken hot or else it soured on the stomach. It is certain that the Institute rarely had its electricity or magnetism served up on cold plates. I know of one president who never attended a single meeting, but his contribution to the art and to mankind would condone vastly greater indifference, just as the verse of Burns, "a tender boon to all humanity, has won pardon for the shortcomings of his brief, chequered life."

Speaking as the senior surviving president of the Institute, it might be expected that I should make some allusion to the nineteen men who have held the office since the beginning in 1884. How some persons get elected to presidential office is a mystery, even granting their great individual qualifications; and it is equally strange how others miss the distinction. It does not follow that because a man is a great engineer or inventor he has the executive ability for leadership; and moreover, he may be right in shunning instinctively that which would only be a distraction from his true work. Two of our most distinguished members, known throughout the

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*Paper read before the Schenectady Section, A.I.E.E., November 1st.

world, have not accepted this office; yet it is surely a matter for congratulation that of the nineteen men no fewer than fifteen have been engineers very distinctively, and the names of seventeen are attached to inventions some of which are the greatest of the last fifty years. This is a large proportion, particularly when it is borne in mind that no fewer than eight of the nineteen have followed the profession of teacher, and three others have been journalists, who speak not as those having authority but as mere scribes. Perhaps the most striking fact about the list and the testimony it bears to the catholicity of the American engineering spirit, as well as the manner in which our national strength is reinforced—is that seven of the nineteen, including the present incumbent, were not natives of this country. The career open to talent that was regarded by Napoleon as such a desideratum, is obviously to be found in this country as nowhere else in the world.

In truth, influential and powerful as the president is under our constitution, he is necessarily like the Institute itself, very much at the mercy of the secretary. To a certain extent the overlapping time classes in the council give, as intended, continuity of experience and tradition, but the personal depository of knowledge and the confidential adviser in all such bodies must always be the man who occupies the secretaryship. It is a singular fact that in three of our great national engineering societies, the secretary should have held office without break for nearly a quarter of a century; and in the Electrical Engineers,' with its rapid growth, its swift changes in the art, and its perenially new problems, we were fortunate to secure a man like Mr. Ralph Pope who is still there and whose worth was publicly recognized this year by the bestowal of a gold medal at the dedication of the Engineering Societies Building. Dr. Keith, with whom in 1883-4 I got up and circulated the petition for the creation of the Institute, went West almost immediately after the first meeting and I was left in charge as a stop-gap secretary. The activity in electrical development at that time was tremendous and I found I could not do justice to my regular journalistic work and to the Institute's affairs at the same time. It was a providential dispensation which gave us at that juncture Mr. Pope's services, for with instant sympathy he took up the work of development that has gone on without cessation to the present moment. Unhasting and unresting, of him it cannot be said that anybody ever saw him in a hurry but the work has always got done. The possession of the lymphatic temperament is, as in him, sometimes associated with a remarkable ability to accomplish. He has never fallen into the error of mistaking restlessness for achievement. Disraeli once compared his Liberal opponents to little children pulling up their plants every morning to see how much they had grown in the night. From such practice the conservatism of our secretary has always saved us, and we have had the growth just the same and all the more. His first report presented in May, 1886, showed a net total of 250 members. We now have over 5,000 not including students, so that our membership has multiplied twenty times in the period. The average budget was then less than $1,000. It is now $70,000. Granting the tremendous development in our field of engineering, it remains evident that only conscientious care and a thorough grasp of the situation could have brought us through all these years to the firm, stable, and prosperous position we now hold.

Comparisons were long since given a bad name, but it is only by noting the progress of other societies that we can realize how far and fast our own Institute has traveled. In the year when the A. I. E. E. was organized, 1884, the American Society of Civil Engineers had 838 members. At the beginning of this October it had 4,287, and by the end of the year will have 4,400. In 1884, the American Institute of Mining Engineers had

1,381 members; on October 5th it had 4,179. At the close of 1884, the American Society of Mechanical Engineers had 557 members and on October 1st it had 3,335 members. Hence, in spite of their flying start and time allowance, the A. I. E. E. has outrun all the other Societies, and with its 5,000 members is distinctly in the lead. I don't know that there is any special credit in this; it is simply a fact worth noting; it may carry an implication or prophecy as to relative numerical importance later on. The growth of these sister societies is reason for hearty congratulation all around. The enrollment in four national technical bodies of nearly 17,000 professional members is surely an indication of the growing influence of engineers and engineering in a civilization that they at least as much as any other factor have created.

Throughout the career of the Institute I have been constantly impressed with the evolutional nature of its growth. What I mean is that at the very outset certain elements and essentials were set forth as desirable, and that persistently, if unconsciously, the society had pursued the ideals of the founders. A perusal of the earliest volumes of transactions shows emphasis to have been laid on a library, a permanent home, branches or chapters, raising the character and qualifications of membership, standardization of apparatus and tests, securing papers on the latest advances and from representative men, and the interchange of courtesies with domestic and foreign societies. Some of these points may be fittingly noted as having been attained much more fully and richly than the idealists and prophets of 1884 deemed possible.

Think of the dignified and graceful home occupied as headquarters in New York, said by an English architect of repute to be of all the buildings he saw in America the best adapted to its purpose. We were homeless cuckoos when we began, meeting here and there, enjoying the hospitality of other societies, like the Civils and Mechanicals, changing our offices eight times in only twenty years, and living from hand to mouth in a manner utterly beneath the status and requirements of a great Institute. The first evidence of nationality is a permanent seat of government, and I for one should have regarded it as a misfortune had the Institute twenty-five years old still been without a definite center, a house and a hearth, a worthy focus for all its activities, and a proper organ for the exercise of all its functions.

At any rate the Institute has answered forever, in satisfactory fashion, the question " Why pay rent? " and is now dealing vigorously with the problem " Why stay in debt? " I am rather proud, though not vainglorious, of the fact that your Land and Building Fund Committee, of which I have the honor to be chairman, has raised in three years from about 1,000 members and friends, the handsome sum of $160,000 nearly all of which is paid in. It hopes to close its debt-lifting campaign this winter by getting the $20,000 still needed. The committee has now and again met with discouragement and disappointment in some quarters where it had high hopes, but will not relinquish its efforts, till the work is done. It believes that the public spirit and active good will of the 4,000 members, who have still to subscribe, will soon free the Institute from all this burden, leaving it with an asset of rapidly increasing value and with all its agencies in unhampered full play.

The joint library in the new Engineering Building given us by Mr. Carnegie is one of the best evidences of the good that flows already from the creation of the new home. There we have what is probably, even now in the earlier stages of organization, the best collection of engineering literature in the world. It is constanly securing valuable accessions, and students more and more frequent it. Together with the grand Public Library on the next street, now being finished, it will constitute the best center of scientific and literary investigation, through the printed world, to be found on this continent. When our past president, Dr. Wheeler, with generous impulse, gave us the Latimer Clark Library, he little thought that from such a nucleus, or so soon, would come in reality, both the building and the splendid larger library it now enshrines. We Electricals are, indeed, not as appreciative as we ought to be of what has come through Dr. Wheeler's initiative and liberal gift—a critical event in Institute history determining all the future.

There has been in some minds the haunting fear that this building and all that it represents, would make for centralization in the Society, for an undue accumulation of power in New York hands; but it is a noteworthy fact that never before was the establishment of branches and chapters carried on so strenuously. Moreover, men who have been prominent in the erection of the building have been most earnest advocates of this policy of decentralization, and past president Scott, one of the foremost in our building work, was as a matter of fact the father of the modern movement that has brought into being such wonderfully successful local bodies as your own, whose usefulness it is indeed hard to compute fully. But if you will go back into the annals and archives you will find that others of us years ago were strong federalists and at the Institute meetings favored policies aiming at the principles approved in the latter days. The vigor of the branches is cause for profound congratulation, the best proof of health; and a pledge of universal interest amongst widely scattered members of the profession, in the work of the Institute.

It would be simply impossible here to review the papers and transactions of the Institute during twenty odd years. A long serried row of 25 substantial volumes, containing 16,000 pages of printed matter, looks at me from my book shelves as I prepare these notes, and picking out any one of them I find valuable fact and data, theory and speculation, from scores of members. It might all have been done better—I know that from serving for years as the chairman of the committee on papers and meetings—but it was something to put into such permanent and readily available form that mass of useful material. As one surveys the great throbbing productive domain of electricity, it seems easy to get all the papers you want, from anybody you choose, but the exact contrary is the fact. I am not ashamed to-day that my own paper and statistics on electric railway work in 1886 were the first of the kind in America, but the literal truth is I was just stage manager called upon to fill a leading role suddenly because the chief actor in the cast was sick.

One of the most agreeable features of the Institute's development has been the interchange of courtesies with kindred societies abroad. We all know the kind of wits attributed to homekeeping youth, and even learned bodies are found to benefit by a sea change. We may yet live to see the Royal Society meeting in Chicago; the French Academy in session at Montreal; and in these days of politics more villainous than saltpetre, let me express the hope that some early day the A. I. E. E. will hold its annual meeting in friendly Tokio, when the cherry trees are all ablossom. Meanwhile, we have had the privilege to entertain in the land of Franklin, the fellow countrymen of Faraday and Volta, of Ampere and of Ohm; and they too have made us welcome in return. I feel confident that in time this closer touch must lead to more intimate union, and that in engineering solidarity we shall find one more pledge and guarantee of the peace of the world. The aptest synonym for engineering is association.

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In closing, Mr. Martin next spoke of the Code of Ethics, recently drawn up by the Institute, and said that while in sympathy with such a code as proposed it should not be made too rigid and too much should not be expected of it.

THE ROSENBERG GENERATOR

By B. M. Eoff

The General Electric Company has recently purchased the American patent rights covering a number of the more important applications of the Rosenberg Generator. The machine was invented by Dr. E. Rosenberg of Berlin, and its method of construction is a radical departure in the field of dynamo design.

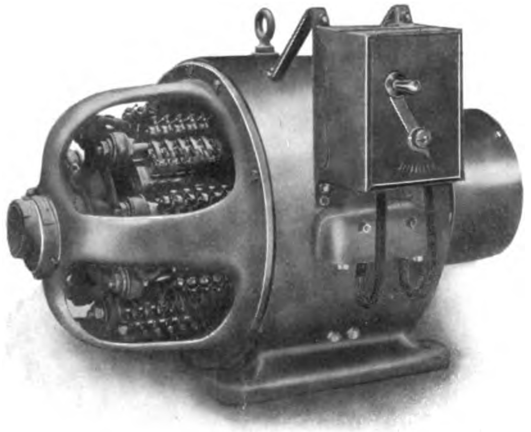


Fig. 1. Rosenberg Generator

The distinctive characteristic that renders the machine especially valuable for certain purposes is its tendency to deliver a constant current at variable speed, and a constant output at constant speed. The means taken to secure these results are very simple and eminently effective; they consist, essentially, in short circuiting what in an ordinary dynamo would be the service brushes, and in placing the actual service brushes at points on the commutator midway between those of the first set. The field cores, at least in the case of a series machine, are designed for a much higher degree of saturation than is usually the case in an ordinary dynamo, and the pole pieces are of different shape and of greater size. In appearances the machine differs but little from a normal generator, as may be seen from Fig. 1, which shows a small series wound Rosenberg machine, fitted with an adjustable resistance in parallel with the field winding, the object of which will be explained later.

The elementary principles upon which the action of the machine is based may perhaps be better understood by reference to Fig. 2, which is intended to show a resolution of the magnetic fluxes into the directions of their respective magnetomotive forces.

This diagram represents a bipolar dynamo, with the armature revolving in a counter-clockwise direction between the pole pieces, marked N and S. The magnetic flux, which may be conceived of as emanating from the pole N and entering the pole S, is indicated in the diagram by the solid lines N S, and for the sake of explanation will be termed the "primary flux."

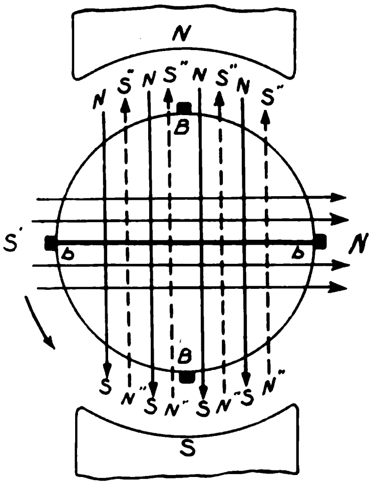


Fig. 2.

Under these conditions of rotation and field, the electromotive force induced in the armature conductors produces a current which flows toward the observer in the upper half of the armature winding and away from the observer in the lower half. This current flowing around the armature and through the short-circuited brushes creates a "secondary flux" at right angles to the primary and indicated by the lines N′ S′.

The current resulting from the conductors cutting this secondary flux creates a tertiary magnetomotive force at right angles thereto in the direction of the broken lines N″ S″, that is to say, in direct opposition to the primary flux. This current is collected by the brushes BB and supplies the external circuit.

With this explanation the action of the machine becomes at once apparent; it is, in effect, in a state of magnetic balance; any increase in current immediately increasing the tertiary magnetomotive force opposing the primary flux, with the result that the current produced by this flux is diminished, the secondary flux reduced, and finally the terminal voltage of the machine. It is evident from this, that at constant speed the generator will have a drooping voltage characteristic and a practically constant output.

At variable speed it is a constant current machine, for an increase in speed tends to raise the voltage and consequently the current; but, as has been shown, this at once reduces serially the primary flux, the secondary flux, and therefore the terminal voltage.

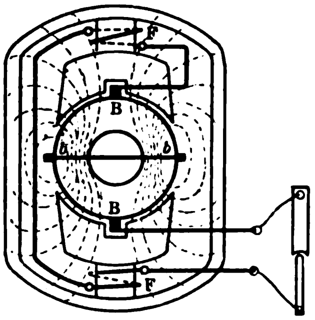


Fig. 3.

Tests made at Schenectady on a one kilowatt Rosenberg generator showed a voltage of 30 when the speed was 1200 revolutions per minute; the speed was then increased to 2600 revolutions per minute, and the voltage rose to 30 1/2, and then fell back to 30; thus, with an increase in speed of more than 100 per cent., the voltage increased but 5 per cent., while the variation in current was slightly smaller.

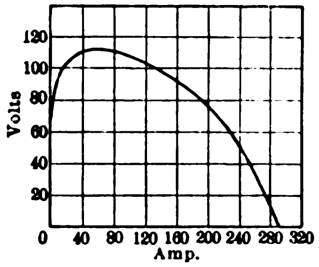


Fig. 4.

For series excitation, the field magnets are built with cores of exceptionally small cross section, and the pole shoes are of unusual size and subtend a large arc on the surface of the armature, permitting the tertiary field to become a strong counter stray field, as shown in Fig. 3.

The number of turns on the field is made large compared with the effective turns of the armature, and for very small currents the primary flux increases at a more rapid rate than the tertiary, with a consequent increase of the terminal voltage; therefore, at the beginning of the curve the characteristic is ascending (Fig. 4).

At a small value of the current, however, the field cores become highly saturated, due to their relatively small area and the large number of turns upon them, while the iron of the armature and that of the heavy pole shoes is still at a very low density. Any increase in current above this value has practically no effect upon the strength of the primary field, but produces in the large volume of iron in the armature core a counter flux which is almost proportional to the current, and owing to this condition, the machine has for the most part a drooping characteristic, as already stated.

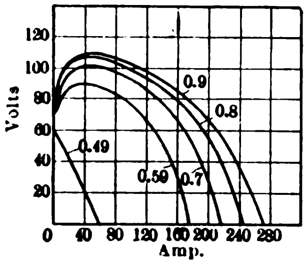


Fig. 5

By suitably dimensioning the various parts of the machine, it is possible to obtain a short circuit current which will exceed the normal current by any required amount, say 25, 50, or even 100 per cent., while on the other hand, the maximum voltage may be made to exceed the normal voltage by a corresponding percentage; furthermore, the machine may be designed to give a drop in voltage almost exactly proportional to the increase of current.

The current for a given voltage may be reduced to any desired value by placing shunts of different resistance across the series field; in which case the field current will no longer be equal to the current at the brushes. Fig. 5 shows the effects of connecting these resistances in parallel with the field winding The decimal given in connection with each curve represents the proportion of the total current that is flowing in the field.

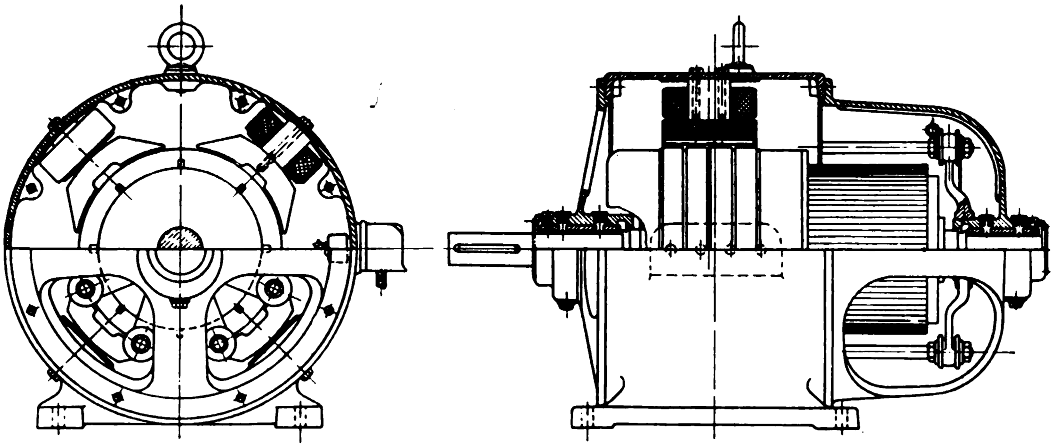


Fig. 6. Sectional Elevation of a Series-Excited Rosenberg Generator Designed for Welding Purposes

If a large open circuit voltage is required, the magnet frame, or parts of it, must be made of cast-iron; since the ability of cast-iron to retain its magnetism is superior to that of cast-steel or wrought iron. The extra weight occasioned by the use of cast-iron is inconsiderable, as in any event the cross sectional area of the magnet yoke is small; and if this is made sufficiently heavy for mechanical purposes, it will amply serve to carry the small flux of the field.

The reduced cross section of the yoke is well illustrated in Fig. 6, which shows two sections of a 30 kilowatt machine designed for electric welding purposes.

The no-load voltage may be further influenced by shifting the brushes backwards or forwards, so that the axis of the short circuited brushes will not be exactly in line with the electrical neutral; under these circumstances the cross flux will have a component which directly strengthens or weakens the residual field, and is productive of widely varying results.

To secure a sufficiently weak field for good commutation at the main brushes, a slot is cut in the center of the pole face from front to back, and on all machines thus far built this has given good results. No trouble has been experienced with sparking or heating at the short circuited brushes.

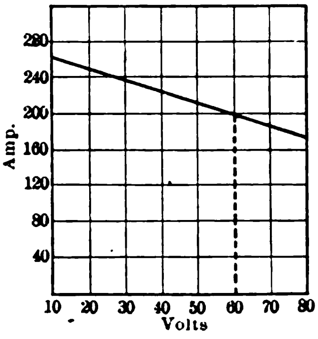


Fig. 7.

The ability of the Rosenberg generator to deliver a falling voltage with rising current, and *vice versa*, renders it especially valuable for use with carbon arcs for searchlights and electric welding; it is, in fact, the best machine known to the profession for the purpose, giving a stability of arc and an economy of operation not approached by any other source of current yet realized.

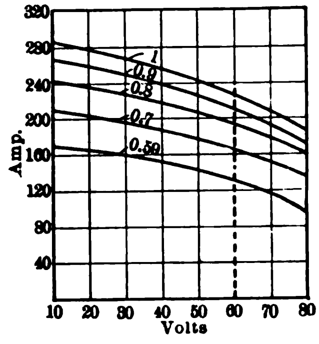


Fig. 8.

This may be readily appreciated when the peculiarities of the carbon arc are brought to mind; for, as is well known, carbon arcs, with the exception of those of very small arc lengths, possess the distinct property, that the greater the current flowing through any given arc, the less the voltage drop across it.

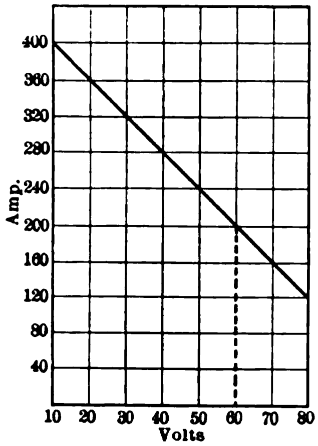


Fig. 9.

Arcs of this nature, therefore, cannot be connected across constant voltage mains without having a resistance—usually termed "ballast"—placed in series with them. The object of this ballast, as its name implies, is to create an electrical balance for steadying the arc; an increase of current producing a decrease of potential at the arc by virtue of the increased drop of potential across this resistance; thereby maintaining the stability of the arc and preventing the otherwise excessively large rushes of current. On the other hand, should the current fall in value, the ballast will produce a rise of potential at the arc, due to the reduced drop in voltage across the resistance, and thus enable the arc to continue burning.

The curve of Fig. 7 shows the currents corresponding to different voltages across the arc of a lamp designed for 60 volts and 200 amperes; the lamp being connected to 220 volt constant voltage mains, and in series with a ballast of 0.8 ohms, which consumes almost three times the amount of power actually absorbed at the arc when working under normal conditions. The curve marked 0.9 of Figure 8, shows the performance of the same lamp without ballast, when connected to a Rosenberg series generator; the generator having a low resistance shunt connected in parallel with its field windings. Upon comparing these two curves it will be seen that they correspond very closely, and that the power saved in the latter case is approximately three times that actually required to keep the arc burning normally. In a lamp connected in series with a ballast consuming only 100 per cent. or less, of the amount of power expended at the arc, the variations of current are greater beyond all comparison than those obtained with the Rosenberg generator. This is shown by Fig. 9, which gives the performance of the above lamp when connected to 110 volt constant voltage mains in series with a ballast of 0.25 ohms.

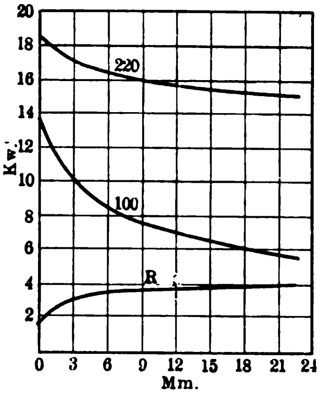


Fig. 10

The curves of Fig. 10, marked 220, 100 and R, show the power consumption, as a function of the arc length, for a 75 ampere arc lamp when connected, respectively, with a series resistance across 220 volt mains; when connected with series resistance across 100 volt mains; and when connected directly to a Rosenberg generator. In addition to the fact that with normal current the power consumed in the first two cases is considerably larger than in the third case, it may also be seen that for small arc lengths the power consumption increases in the former cases, while in the latter case there is an actual decrease of power. With a complete short circuit, the machine will require but little more power for driving than when open circuited.

This last named feature of the generator, *i.e.*, the inherent impossibility of its being subject to heavy overload, opens up another extensive field of application for the machine in connection with gasoline-electric conveyances, both for railway service and for street bus lines; taking as an example of the latter, for instance, the Fifth Avenue bus, of New York City.

For service of this kind the series generator is the more suitable, because of its ability to deliver an almost constant output with widely varying currents; and further, because this means of excitation provides against an overloading of the driving engine. When climbing grades the motors naturally tend to slow down, a larger current flows through them, and the voltage of the generator automatically drops; thus, no regulating resistance need be interposed between the motors and the generator, and they may be connected by means of a simple switch directly to the generator while the latter is running.

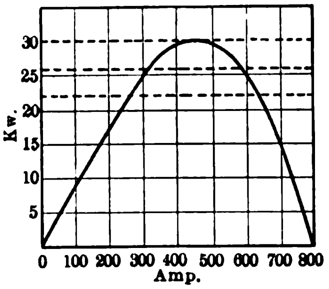


Fig. 11

Figure 11 shows the output in kilowatts corresponding to the external current of a small series generator with full field excitation; *i.e.*, with no shunt in parallel with the field winding. The maximum output of 30 kilowatts is attained with a current of 450 amperes, and any increase or decrease of current above or below this value will result in a decrease of power output. If we consider 26 kilowatts (represented by the central dotted lines) as the normal capacity of the generator, the current may then have any value between 230 and 670 amperes, with a variation in power output not exceeding 20 per cent. of the normal. The voltage, as determined from a curve similar to Fig. 4, is found to vary between 30 and 86 volts. It is thus seen that the machine represented has a practically constant output within wide limits.

The Rosenberg generator may be further used as a reversible booster placed between two sources of variable voltage, such as a battery of 50 cells and a 110 volt generator; the voltage of the latter varying between 90 and 130 volts. If the voltage of the generator and battery are the same, a current equal to the short circuited current flows through the booster, since the terminals of the machine are at the same potential. If, however, the voltage of the generator is greater than that of the battery, the current through the booster will increase slightly above the short circuited current, the tertiary flux will overpower the primary, and the booster will generate a negative voltage; in other words, the machine will run as a motor, consuming the difference between the voltages of the generator and battery. Should the voltage of the battery be greater than that of the generator, a current somewhat smaller than the short circuited current will flow, the booster will generate a positive voltage, and the potential between the two circuits will thus be equalized. The machine, when used as an ordinary booster for charging accumulators from constant voltage mains, will require no regulation throughout the whole range of charging, from full discharge to complete charge. The current decreases with progressing charging, either very slowly or at any predetermined rate, depending upon the design of the machine, while the voltage of the booster adjusts the line voltage to that of the battery. Figure 12 shows the performance of a machine when operating under these conditions. For mains supplying very irregular service, the excess of current above the average may be supplied by a buffer battery; and by placing a Rosenberg generator between the mains and the battery, the mains will then supply the average power required throughout the hours of service. The booster, as has been shown above, will operate as a motor or as a generator, depending upon whether the voltage of the mains is above or below that of the battery, while the current flowing through the booster will remain almost constant. This arrangement is outlined in Fig. 13.

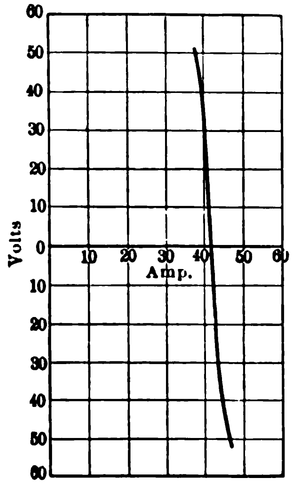


Fig. 12

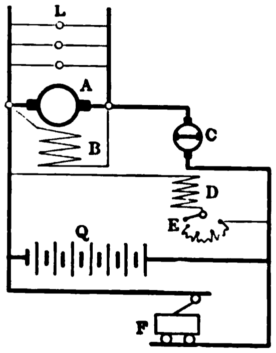


Fig. 13

FORM 2 MULTIPLE LUMINOUS ARC LAMP

By G. N. Chamberlin

The luminous metallic arc is now recognized as the most efficient and best all-around street illuminant in commercial use. This system of street lighting as furnished by the General Electric Company, having passed the experimental stage, is in quite general use, and one or more of the other large manufacturers are entering the field of development and exploitation.

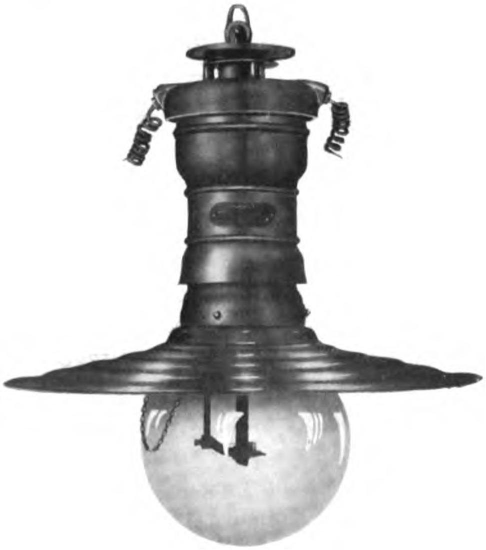


Fig. 1

Form 2 Multiple Luminous Arc Lamp

For low voltage, direct current, multiple circuits, 100 to 125 volts, there has been but little use made of the metallic lamp. A lamp for use on such circuits was described in the September, 1906, issue of the General Electric Review. This multiple lamp was a modification of the series lamp, requiring in addition to the necessary regulating magnets and steadying resistance, shunt magnets for striking the arc, and a cutout for protecting the shunts.

It was thought advisable to develop an improved type, as shown in Figure 1, which resembles quite closely in outline and general dimensions the standard type of General Electric enclosed lamp. The lamp is of pleasing appearance, and of suitable size for installation on multiple circuits.

The casing is of solid copper with a black oxidized finish. The main body of the casing is rolled from one sheet of .030 copper, thus eliminating all riveted connections, and furnishing a strong and durable housing for the lamp mechanism, and a support for the outer globe and its supporting ring.

The standard No. 5 outer globe is used, but the lower surface is ground to eliminate shadows directly underneath the lamp, and to obscure from view the small metal pan, placed in the bottom of the globe to catch the iron oxide. The globe supporting ring is a slight modification of the one now in general use on General Electric multiple enclosed arc lamps.

Figure 2 is an interior view, showing the mechanical construction of the lamp. The main frame consists of a 1½ in. iron pipe connecting the top and base castings, forming a rigid construction, and at the same time providing a suitable center draft or chimney for disposing of the arc fumes. At the top this chimney is protected from rain and storms, in such manner as not to interfere with the natural and uniform draft required at all times for the proper action of the arc flames.

The upper, or positive electrode consists of a T-shaped drop-forging of copper. With a large volume of copper and a large radiating surface, it is possible to keep the electrode at a low temperature, and this condition, together with the peculiar characteristics of the luminous arc, results in a slow wearing away of the copper. To further decrease this oxidization, and increase the life of the copper electrode, an iron tube is fitted tightly around the latter, leaving the copper end bare for the arc contact. With a 4 ampere lamp this upper electrode will require renewing after about 1800 hours operation; or, with an average burning of five hours per day, this upper electrode should last a year.

The lower electrode, which is responsible for the characteristic flaming arc of this lamp, is an iron tube $\frac{11}{16}$ in. in diameter and $5\frac{3}{4}$ in. in length, filled with the prepared composition. One electrode only is used at each trimming, with a life of about 150 hours.

The non-consuming copper electrode, and the electrode box, are attached to and carried by a non-corroding Benedict nickel tube. This tube passes inside of the draft chimney, and comes in contact with, and is carried by, the lamp clutch. This clutch consists of five phosphor-bronze balls, wedging between an inclined plane of the clutch ring, and the tube to be lifted.

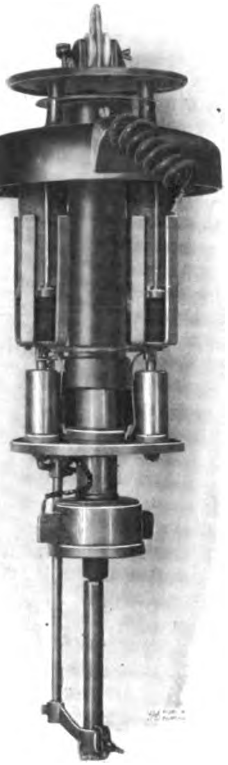


Fig. 2
Interior of Lamp Showing Construction

There are two single magnets, with the two E armatures mechanically connected. This single solenoid construction, with the E shaped armature, has been recently proven to be one of the best, if not the best, of magnet constructions available. Its action is positive, and at the same time remarkably sensitive, responding quickly to any variations of the line or arc, and thus maintaining a close regulation of the current.

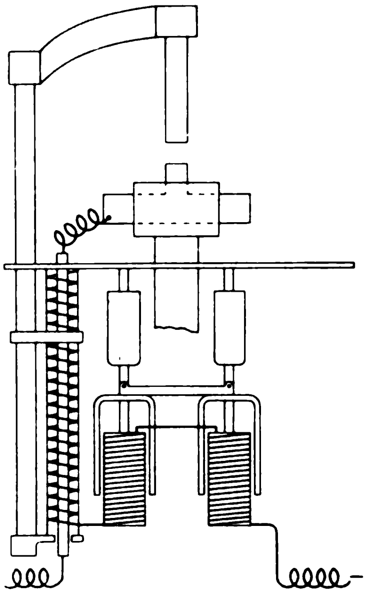


Fig. 3
Diagram of Connections

The magnet windings, as well as the resistance, are of the wellknown edgewise type. All leads are insulated with glass beads, presenting a modern indestructible lamp.

Two 1 in. dashpots are used, which provide the necessary retarding effect, with a large clearance between the shell and the graphite plunger.

Figure 3 shows the extreme simplicity of the connections. Only the electrodes, lifting magnets, and steadying resistance are in circuit, and these are connected directly in series. The lamp is equipped with leading-in cables on account of the fumes which might accumulate and ground metal binding posts on the lamp top.

The larger users of arc lamps now specify that lamps shall be furnished without switches and the majority of small stations do not use the lamp switch when it is available. The magnetite lamp will be furnished without switches.

Figure 4 shows a comparison of photometric measurements of a 5 ampere D.C. enclosed arc, a 7.5 ampere A.C. enclosed arc, and the 4 ampere magnetite arc. Even with the decreased wattage the increase of candle-power is noticeable. The characteristic distribution of the metallic flaming arc, with its maximum intensity near the horizontal, is well known. This natural distribution can be changed to meet other street lighting requirements by the use of correctly designed concentric wave reflectors, as is plainly shown in these photometric curves.

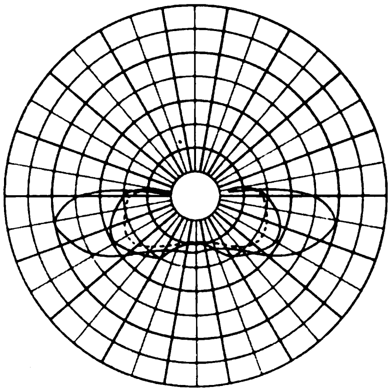


Fig. 4
Curve Showing Photometric Comparison

Four amperes and 73 volts at the arc will be the standard adjustment for 110 volt circuits. Special windings for 4.5 or 5 amperes can be furnished, if required, but the electrodes give shorter life when operated at the higher current.

In general, the lamp needs little attention; less, in fact, than the enclosed lamp, as there are no enclosing globes and gas caps to require careful handling, cleaning and renewing. At each trimming it is necessary to clean the center or draft tube, and also the box containing the upper electrode. A suitable brush is provided for the purpose.

A small metal ash pan is furnished, which is to be placed in the bottom of the globe. This pan catches the reddish brown particles given off by the burning away of the lower electrode, and can be easily emptied at each trimming. Some of the fumes go through the draft tube and out into the air, thus rendering the use of the lamp objectionable for certain indoor installations, where such fumes would be deleterious. The lamp is specially recommended for the lighting of foundries, machine shops, train sheds, freight houses, freight yards, drill halls, and riding academies, or in general, for the lighting of large areas where the fumes are not noticeable.

It is imperative that this lamp be so connected that the composition electrode is negative. To facilitate the correct connections being made to the circuit, the lamp top is plainly marked "positive" and "negative" above the respective leading-in cables.

Should the lamp be operated with the copper electrode negative, it will burn with a low efficiency copper arc, which will continually rupture itself. Such operation will cause a very rapid disintegration of the copper electrode, as well as a general abuse of the operating mechanism.

Modifications of this lamp are suitable for 220 volt multiple, and multiple series power circuit operation. These lamps will be described in a later issue of the GENERAL ELECTRIC REVIEW.

THE ELECTRIC HEATING SITUATION

By E. L. Callahan

The summer has shown a substantial advancement in making popular the use of electric heating devices, which is not only apparent from the increased sales recorded, but is further made evident by the growing confidence shown by the central station men in their ability to sell the devices to their customers.

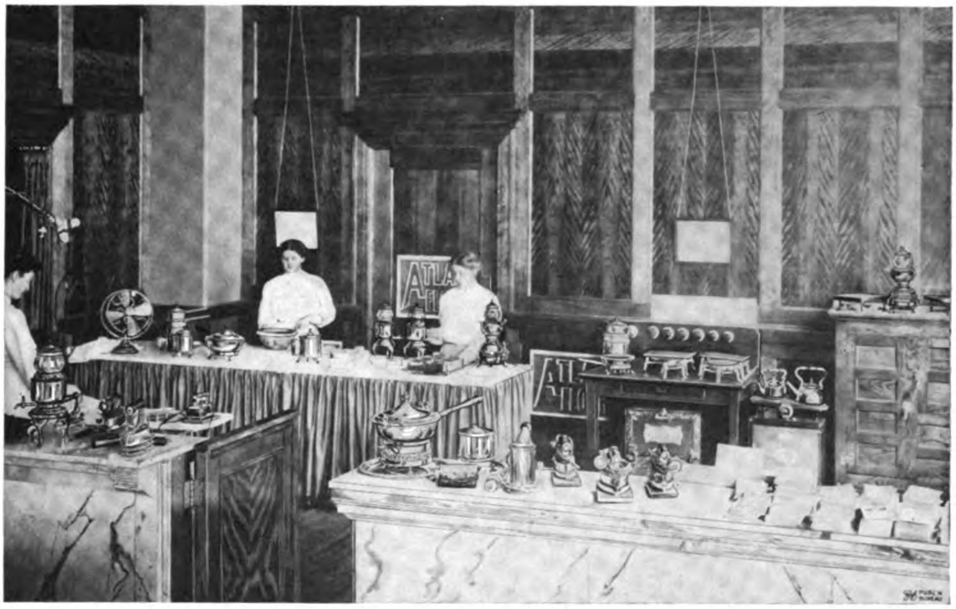


Fig. 1. Demonstration Room of the Milwaukee Electric Railway & Light Company

Last year, and the year before, the General Electric Company sold heating devices to their customers for the first time. In many cases the customers took the word of the salesman that a very profitable revenue could be obtained from handling this class of apparatus, and they were not disappointed in the profits derived from their flat iron business. However, few if any of these central station men thoroughly grasped the situation, for they had not as then realized that there was a great future for them in heating devices. They were willing enough to have a boy peddle out a hundred irons and accept the increased revenue, but as for planning for the business and its future, they were "too busy to give it much thought," or had been "changing the plant over to 50 cycles;" or again, they had been "busy on the new plant in order to carry the present load over next winter's peak."

With the exception of a very few stations, the subject of installation, systematic advertising, and the establishment of rates has just begun to be threshed out.

My criticism of central station progress may seem to contradict the statement made above of substantial advancement, but to one who has studied the progress of electric heating for some time, there is every reason for taking an optimistic view of the situation; for, even if a very small beginning has been made on the whole, it is a *good* beginning. Central station managers have learned that heating devices cannot be sold over the counter like so much sugar; on the contrary, the majority of them are convinced that it will pay to employ expert heating salesmen to lay out well formulated plans for this end of their business. The electric heating manufacturing companies are to be congratulated on the good results obtained under trying circumstances: for not only the central station man has had to be won over before he could be induced to buy devices not actually necessary to his business, but it has been hard to hold the customer and his interest when the field was so large that the demand was beyond the capacity of the factory to supply. With a product more easily standardized, we are led to believe that this handicap will soon be removed.

A most prosperous year for 1908 may be looked forward to, for the heating business throughout the country is in a healthy condition. There are but very few day circuit central stations that have not placed initial orders; some are discouraged and have done nothing further, while others have forged ahead and have obtained results which have more than justified the heavy expenses incurred in establishing the business. There is an atmosphere of development and of pushing ahead pervading these backward stations, and if for no other reason than to follow the example of their older and wiser brothers, they will break away from this conservatism and former unprogressiveness.

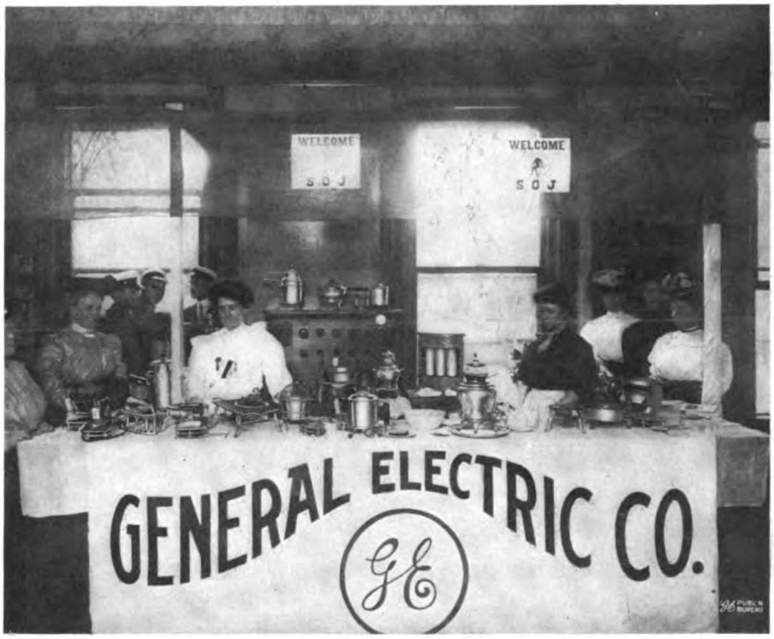


Fig. 2. Exhibit at Oklahoma State Electrical Convention, Oklahoma City

Full credit cannot be taken by the central station men for the good results in business obtained from the use of heating devices, for the General Electric Company has been instrumental in educating the public, through extensive advertising in magazines, technical papers and bulletins, to new and novel applications of electricity. Much data has been published, giving convincing results and cost of operation; and showing the practicability for every day use of electric heating devices. The result of this has been to attract the public eye, and to excite curiosity and requests for more information, with the further outcome that central station customers are much more willing to give electric heating a trial.

One of the most important things to be observed by a salesman or solicitor is the close following up of a prospective customer; if this is not done, hard earned advantage may go to a competitor, or the customer may lose interest, and it may not be possible to again arouse the necessary enthusiasm. "Following up" likewise means to find out and remedy troubles that may have been had with apparatus; for, with the best designed and constructed apparatus, little difficulties, real and imaginary, will occur; very often through ignorance on the part of the one who uses or installs the device. People should not be allowed to use things ignorantly; the persons who are interested in inducing the public to use and enjoy electric heating devices are under obligations, from a business point of view, to keep the customers satisfied.

The writer considers that we have not progressed far enough along into the heating business to fully judge of the field, but that it is large there is no doubt. For instance, the problem of furnishing electrically heated water in the summer time for bath and kitchen purposes, has scarcely been solved by the manufacturer, and not at all by the central station man. We must help the latter determine the best practical method of providing his customer with a "readiness to serve" power, of from 5 to 15 kilowatts. He must make it an easy matter to install complete kitchen ranges or outfits; manufacturers in his town will want to use glue pots, electric air heaters, pressing irons, soldering irons and special applications of heat, and the central station must make it possible for them to get the power readily; in other words, he must go after the heating business.

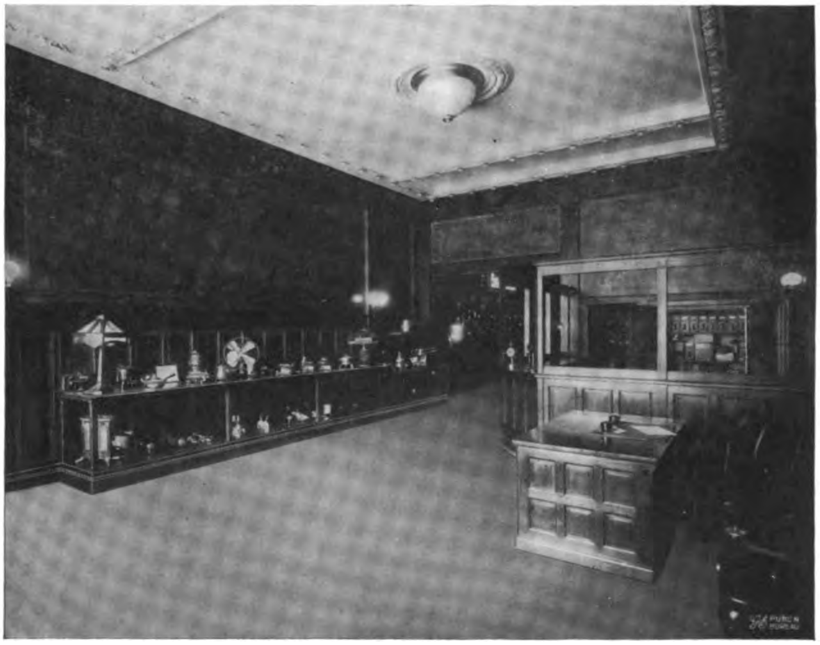


Fig. 3. Exhibition Room of Grand Rapids-Muskegon Power Co.

I could name a score of central station managers who have told me, with considerable boasting, that they have made a canvass of their likely customers, with the result that an iron has been placed in one out of every ten homes. They seemed perfectly well satisfied to drop aggressiveness in pushing for further sales, taking it for granted that the remaining 90 per cent. would never think later of following the example of their neighbors. Then there are some of our good friends who "skim the cream" of their community and, pay no further attention to keeping the devices sold in working condition, condemn the manufacturer, and turn to another and another; until the customer, and they as well, are dissatisfied, and can see nothing in electric heating.

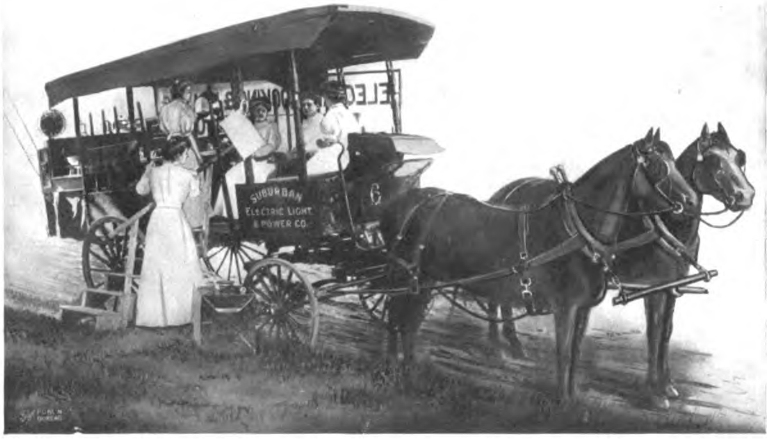


Fig. 4. Demonstration Wagon at Webster Grove, Missouri

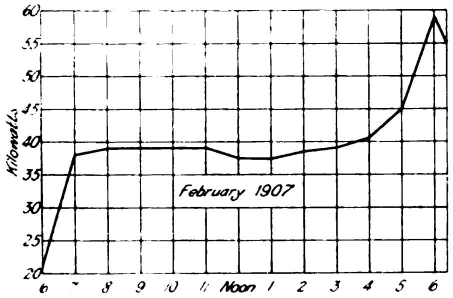
In such a city or town one would see a lack of lamp renewals, and plenty of reasons for dissatisfaction on the part of the consumer. Such a central station man needs to learn that a *satisfied customer helps a public corporation pay dividends*.

There are central stations, however, that contrast sharply with the ones we have had in mind. At Webster Groves, Missouri, much heating business has been obtained through the use of a demonstration wagon shown in the cut above. The arrival of this wagon was announced a day in advance by postal or letter, and the demonstrator would cook and iron, with a good audience at each stop.

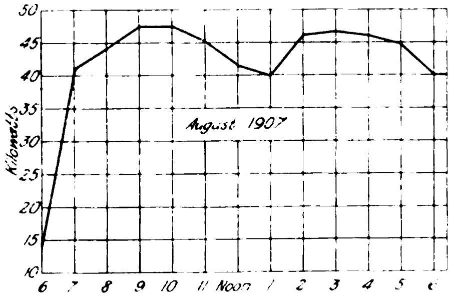
One Chicago supply salesman, in Iowa alone, has induced nine small towns without day circuits to operate this summer on Tuesdays (ironing day), with the result that they find it a paying proposition which will soon make it lucrative to operate every day in the week. Each of these towns now have from fifty to one hundred and fifty flat irons, which have been placed in service since about July 1st. At Washington, Iowa, fifty irons were put out on approval in one day; forty-one of them stayed in service, and several of the nine customers, who returned the irons then, came back for them later. The superintendent of this plant says he cannot see that this flat iron trade has affected their gas business in the least. Their customers, and customers in other towns, have increased their bills for current by amounts of from forty cents to one dollar, but all seem to be perfectly willing to incur the added expense for the conveniences provided by the electric current.

In another small town in Iowa, the gas and electric company would not handle the the irons; a local plumber then bought fifty irons, and sold all of them at $5.00 each. We hope that the central station will not be outdone by the plumber next summer, but that it will help him place more current consuming devices on its lines. The rate charged is 15 cents per kilowatt hour, and the lighting company realizes that the revenue derived from the use of flat irons is nearly all clear profit.

The reader's attention is called to the load curves above, where Curve 1 shows the kilowatt load over a period of 12 hours, from 6 a.m. to 6 p.m., for February, 1907, in a city of 19000 inhabitants. Curve 2 shows the load for the following August, after one hundred and twenty-five flat irons, (the equivalent of eighty-four horse-power) and one hundred horse-power in motors had been installed on the circuit. The writer was very glad to get such a good illustration showing the desirability of installing electric cooking apparatus to make the curve more nearly approach the ideal straight line.



Curve 1



Curve 2

At conventions central station men have discussed the effect of this cooking load on their lines, and the majority of them believe that the station peak will not be increased in summer, and not to a prohibitive extent in winter. It seems, from the curve of Figure 2, that in this particular town it would be very desirable to have a cooking load of at least fifty kilowatts, to correct the curve; this would represent some twenty-five or forty families using electricity exclusively to cook with. The advisability of carrying a cooking load above this value would depend upon the ability of the plant to carry load above its present peak. With the exception of baking, nearly all cooking is done between the following hours:

Breakfast	5 to 7:30 a.m.
Lunch	11 to 12:30 p.m.
Dinner	5:30 to 7 p.m.

with dinner usually at noon in the smaller towns.

The reader is referred to the October number of the Review for data on current consumption for cooking for a family of three.

Central station men need all the help the manufacturers can give them, and they are glad to see the salesman when he calls, for they expect to hear the news — to learn of new developments and experiences of other stations. I am aware that the greatest help the manufacturer can render the central station man is to make him prompt deliveries of apparatus; and next in importance to this is to secure for him men who are expert heating solicitors, who will spend a month or two in organizing his heating department, and in training men to carry on the business along the lines mapped out by himself. The writer hopes that the General Electric Company will soon be able to furnish a number of such expert solicitors to central stations at reasonable salaries, so that they can carry on their heating business in an intelligent and aggressive way, and thus gather in some of the profitable revenue that is waiting for the wide-awake ones.

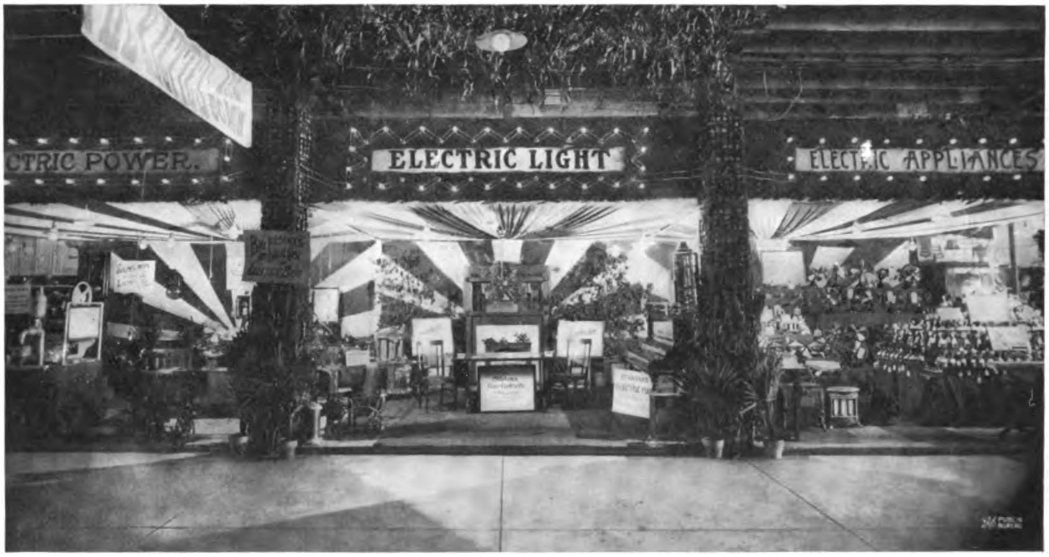


Fig. 5. Corn Carnival Exhibit of the Oklahoma City Gas & Electric Co.

I know of some stations that would be compelled to discontinue their day service if they were deprived of their electric heating load, and it is gratifying to know that the central station managers throughout the country are planning to get all the electric heating business they can. In a letter from a local lighting company at Adrian, Mich., the manager states that they have erected on the roof corner of their building, a seven foot electric sign which reads, "Now is the time to use electric flat irons," and in the space between the words "flat" and "irons," a General Electric flat iron is represented in outline by two-candle-power incandescent lights. This sign happens to stand directly over the center of the street, due to an angle in the latter, and can be seen from far and near.

Central station managers are spending much money in fitting up attractive demonstration and exhibition rooms, in order to show their customers electrical conveniences in operation. They consider money spent

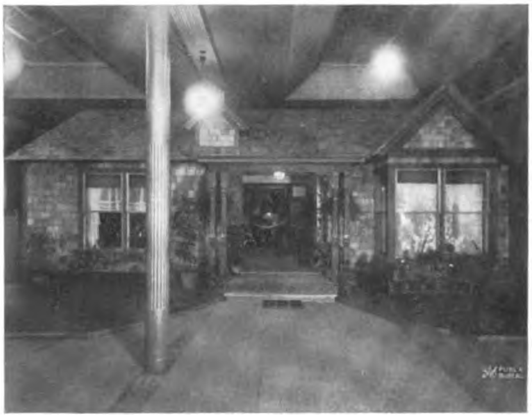


Fig. 6. Six Room Cottage Completely Equipped with Electrical Devices, in Display Room of Union Electric Co., Dubuque, Ia.

in this way well invested, with the belief that it will bring them abundant returns.

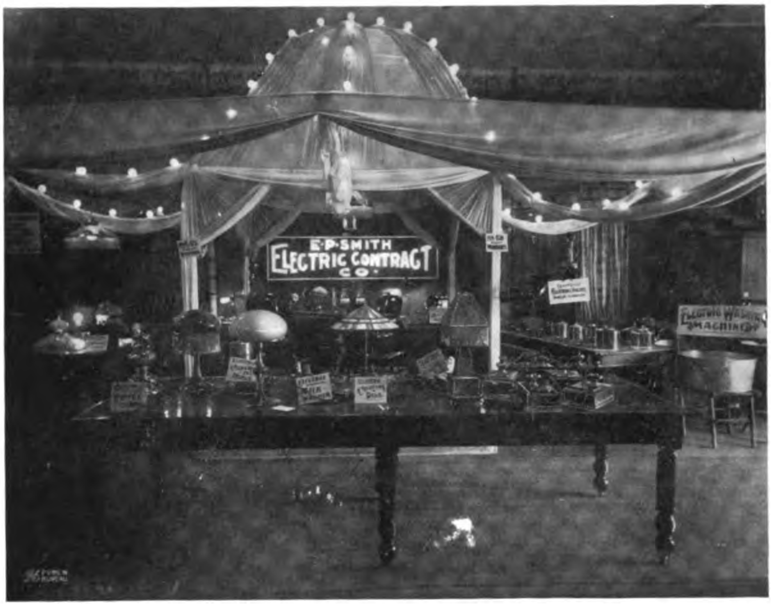


Fig. 7. Exhibit of Electrical Devices, Dubuque, Iowa

The domestic science department of women's clubs is enthusiastically taking up and advocating cooking by electricity, and in many cities the local lighting companies co-operate with these clubs by furnishing lectures and demonstrators, as well as space and attractive exhibits, with the result that their heating business is greatly increased.

Another article will appear in a subsequent issue of the Review, containing several illustrations of demonstration and lecture rooms, where well attended sessions have been held, and much interest shown in the display and operation of heating devices.

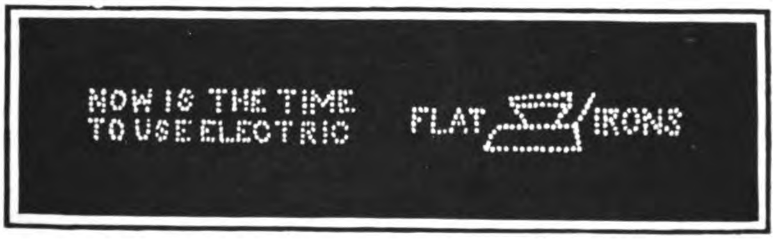


Fig. 8. Electric Sign on Roof of Local Lighting Company, Adrian, Mich.

TRANSIENT ELECTRIC PHENOMENA *

PART I

By Dr. C. P. Steinmetz

When electric power flows through a circuit, power is consumed in the conductors of the circuit by their resistance; and this loss of power takes place as long as the current flows, and equals i^2r; where r is the resistance of the conductor. Accompanying the flow of power through the circuit, a magnetic field, and also an electrostatic field exist in the space outside of the conductor; these are essentially as much a part of the phenomenon as the loss of power in the resistance. The lines of magnetic force surround the conductor in closed circuits; the lines of electrostatic force radiate from the conductor and terminate in the return conductor. The magnetic field is proportional to the current, and equals iL—where L is called the *inductance* of the circuit. The electrostatic field is proportional to the voltage, and equals eC—where C is called the *capacity*.

No power is consumed in maintaining the magnetic or the static field, but energy is required to produce them, and this energy is stored in the space outside of the conductor as magnetism, or as electrostatic stress; and is returned, or dissipated, when the magnetic, or static field is destroyed.

The magnetic energy is $\frac{i^2L}{2}$; the static energy $\frac{e^2C}{2}$, just as in a moving mass the mechanical energy is $\frac{v^2m}{2}$.

In an alternating current circuit, where current and voltage periodically vary, the stored energy of the electric field also varies; its magnetic component reaching a maximum at maximum current, and its static component at maximum voltage.

Since the flow of current necessitates storage of energy as magnetism, it follows that a current cannot start and reach full value instantly—just as a fly-wheel cannot instantly reach full speed. The current, when closing an electric circuit—like the speed of a fly-wheel—starts from zero and gradually rises to full value; and during this period of acceleration, not all the power which flows into the circuit is delivered at the other end or consumed by the resistance, a part is stored as magnetism. For the same reason, a current cannot stop instantly; its magnetic energy must first be dissipated or returned to the electric circuit, just as a fly-wheel cannot stop instantly. Just as an attempt to instantly stop a fly-wheel, by a rigid obstruction, results in the momentum of the fly-wheel exerting a practically infinite force upon the obstruction—that is, in breaking it—so the attempted instantaneous stoppage of the current, and thus the instantaneous dissipation of its magnetic energy, would induce an infinite e.m.f. in the circuit, that is, would result in disruption.

Therefore any change of current due to a change of circuit conditions, is not instantaneous, but gradual; there being a transient period during which magnetic energy is stored—if the current be rising,—or returned to the circuit—if the current be decreasing. During this transient period the current has not the normal value that would correspond to the circuit conditions, but there is a transient term of current which connects the previous value of current with the value of current that follows after and that corresponds to the changed conditions.

If then in a circuit carrying current i_0, the conditions—such as resistance, voltage, etc.—are suddenly changed so as to produce a current i_1, the actual current i does not instantly jump from value i_0 to value i_1, but gradually approaches it; first rapidly, and then slower, as shown in Fig. 1. Instead of saying that during this transient period the current does not have the normal value i_1, but has the value i, we can say that during this time the current in the circuit consists of the current i_1 plus the current $i_2 = i - i_1$, hence we have:

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* Lecture presented before the Schenectady Section, A.I.E.E., October 18th.

$$i = i_1 + i_2$$

the current i_1 is produced by the impressed voltage of the circuit. The current i_2 therefore, has no voltage back of it, but is merely a survival of the change; it results from the fact that at the moment of the change, the current in the circuit is different from what it *should* be to correspond with the changed conditions; and consequently this current i_2 gradually dies out, that is, it may be called the "transient current of change of circuit."

If the impressed e.m.f., and therefore the current, are alternating (as in Fig. 2), and if at the moment of a change of the circuit, the current has the instantaneous value i_0, but *should* by reason of the changed condition of the circuit, have the value i_1, then the actual current i will gradually approach the normal current curve I_1 from the previous value i_0. That is, it consists of the two current components $I_1 + i_2$; where I_1 is the alternating current produced by the impressed e.m.f. under the new circuit conditions, while i_2 is the dying out of the difference $i_0 - i_1$, with no voltage back of it; that is, it follows the same curve as in Fig. 1. In other words, the transient current i_2, merely depends upon two things; first, the discrepancy between the *actual* current i_0, and the current i_1 which *should* exist after the change; and, second, upon the circuit conditions. It does not depend upon the character of the power flow, whether continuous or alternating; it has no voltage back of it, and can be investigated as current flowing in the circuit at zero impressed e.m.f.

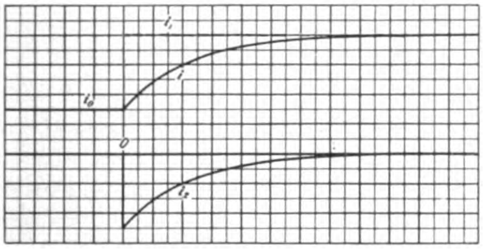

Fig. 1

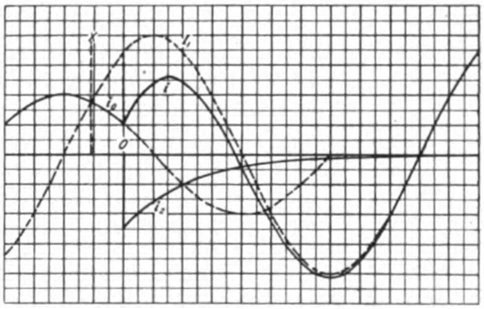

Fig. 2

The change of current with a change of circuit conditions, that is, the readjustment of the circuit to the changed conditions, —which is the dying out of the transient term i_2—is the slower, the higher the inductance L of the circuit and the greater the difference between the previous value i_0 of the current, and the after value i_1, that is, the more magnetic energy there is to be stored or returned. Hence, in a highly inductive circuit, as a motor field, it may require several seconds before the current becomes normal; while in a practically non-inductive circuit, as in an incandescent lamp, the change is practically instantaneous. If at the moment when the change in the circuit occurs, the current which *should* flow in the circuit, under the changed conditions, happens to be of the same value as the current *actually* flowing—as for instance, at the point x in Fig. 2—no transient term appears, but the current immediately follows the normal value.

Upon closing an alternating current circuit at that moment of the e.m.f. wave when the current should be zero, no transient term appears; while upon closing the circuit at the moment when the current *should* be maximum, the transient term is a maximum since the actual current is zero.

These transient currents are rarely of practical importance as currents, but their importance lies in the voltage which may be produced by them, especially in the extreme case when the current is decreased to zero, that is, upon opening the circuit.

When opening a circuit, the stored magnetic energy must be dissipated during the opening of the circuit, or, while the current is decreasing to zero; and if we attempt to open the circuit instantly, that is, infinitely fast, the magnetic energy must be dissipated at an infinite rate, *i.e.*, at an infinite e.m.f. The faster an electric circuit is opened, the higher, therefore, is the e.m.f. induced at the opening switch by the decreasing magnetic field of the circuit; and if the magnetic energy is considerable, as in the case of a motor field, and the circuit is opened with a quick-break switch, the induced voltage of the magnetic field discharge may easily reach disruptive values.

Where the currents are very large, and are normally of high voltage, as in high power alternating current systems, a sudden opening of the circuit is liable to be destructive, if it does not take place at the zero point of the current wave; that is, at that point where no transient term appears. A break in open air, with a long flaring arc, is dangerous in this respect, in that the arc frequently has a tendency to rupture when near the maximum value of current, thus giving disruptive induced voltages. Thus the transmission and distribution of very large power has become practically feasible only by the development of the oil switch, which has the characteristic of opening the circuit at the zero point of the current wave, due to the opening occurring through an arc at high vapor pressure—that produced by the momentum of the oil column.

In addition to that stored in the magnetic field, energy is also stored by the electric circuit as electrostatic energy, by the electrostic field of the circuit; or as is usually said—in survival of the ancient theory of electricity as a fluid—by the electrostatic charge of the conductor.

In most circuits, such, for example, as the low voltage lighting circuits, the 550 volt direct current railway circuit, and the 2200 volt alternating current distribution circuit, the electrostatic energy, $\frac{e^2C}{2}$, is so small, compared with the magnetic energy $\frac{i^2L}{2}$, that the former can usually be neglected (except when dealing with extremely high frequencies, as in lightning) and the circuit considered as having resistance and inductance only, and no capacity, that is, as storing energy only magnetically.

The static energy is comparable with the magnetic energy, or of the same magnitude, in only two types of circuits:

1. The long distance high potential transmission lines, or high potential underground cable systems. Here the voltage e is so high, or the capacity C so great, that $\frac{e^2C}{2}$ is of the same magnitude as $\frac{i^2L}{2}$, that is, in overhead lines of 30,000 volts and over, and in underground cable systems of 6,600 volts and over.

2. The telephone circuit. Here the currents are so small and the frequencies so high that $\frac{i^2L}{2}$ is of as low magnitude as $\frac{e^2C}{2}$.

The long distance transmission line and the telephone circuit thus show many similarites in their electric phenomena, resulting from the storage of energy in two forms, as magnetic and static; the effects obviously are vastly different, due to the negligible power in the one type of circuit, and the very large power, high voltage, and large current in the other type of circuit.

In these circuits in which energy is stored in two forms, statically and magnetically, any change of circuit condition usually requires a readjustment of both forms of energy. That is, two transient terms exist, one resulting from the change of current from the value i_0 (corresponding to the previous conditions), to the value i_1, required by the changed conditions; the second transient term corresponding to the change of e.m.f. from e_0 to e_1, or of electrostatic charge from q_0 to q_1.

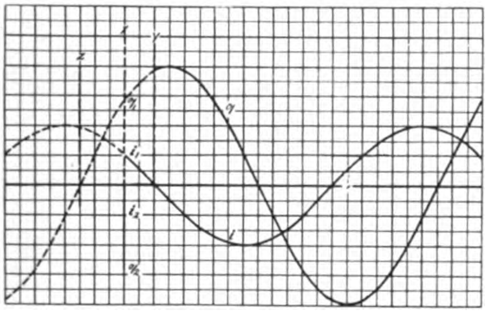

Fig. 3

For instance, if in Fig. 3, i is the current and q the electrostatic charge, and thus the voltage of the circuit; and if the circuit is closed at the moment marked x; at this moment the current *should* be i_1, but is in reality zero; and the static charge should be q_1, but is also zero. Thus starting from zero at x, the actual current and voltage gradually approach the permanent values i_1 and q_1; hence they can be considered as consisting of two terms:

$$i = i_1 + i_2$$
$$q = q_1 + q_2$$

where i_1 and q_1 are current and static charge, produced by the impressed e.m.f. under normal circuit conditions, and i_2 and q_2 the transient terms of current and static charge, backed by no e.m.f., and consequently gradually dying out.

If the circuits are closed at that moment y, where the current is zero, a transient term would still appear, due to the voltage, which at this moment is not zero; and if the circuits are closed at the moment z of zero voltage, the current, which is not zero, produces a transient term. Therefore upon closing (or opening) such a circuit, containing inductance and capacity, the transient term can only disappear if both current and voltage pass zero at the same moment; that is, if they are in phase, or the circuit in resonance condition. The disapperance of a transient term would therefore require that capacity and inductance of the circuit have such values as just to neutralize each other, and also that the circuit be closed at just the proper moment of the wave; and since the coincidence of so many conditions is highly improbable, it can be said that in general: "in a circuit containing inductance and capacity, upon closing or opening the circuit, or in any other way changing the circuit conditions—as by a change of load—a transient term always appears, due to the readjustment of the magnetic energy or the static energy, or both."

If the circuit is closed at the moment y, where the current should be zero, the magnetic field of the current produces no transient term, but the electrostatic field of the voltage does. The transient term (Fig. 3) produced by the latter, however, comprises not only voltage, but current also. At the moment of closing the circuit, the static charge on the conductor should be q_1; it is, however, 0. That is, the circuit represents an uncharged condenser thrown across the e.m.f., and in the first moment, the condenser acts as a short circuit on the supply voltage. That is, short circuit current rushes into the condenser and charges it to the required voltage e_1. At the moment where the condenser is charged to its normal value, the charging current still is excessive, and consequently its magnetic energy is also excessive; hence, it cannot instantly disappear, but continues flowing into the condenser, thus overcharging it, until all the magnetic energy of the current has been stored as static energy in the condenser, charging it above the voltage which it should have, that is, to about twice line voltage. As soon as the current has been stopped by the rising counter e.m.f. the latter begins to discharge, causing a reverse current to flow. This current is a maximum when the condenser has discharged down to its normal voltage; the current continues to flow, discharging the condenser, and again causing the current to reverse and to recharge, and so on.

The same phenomena appear when closing the circuit at zero e.m.f. (point z of Fig. 3). At this moment the current should have the value i_1, but instead, is zero, and so a transient current appears. This, flowing into the condenser, charges it to a voltage beyond the normal, causing the reverse discharge current to flow, with its accompanying phenomena outlined above.

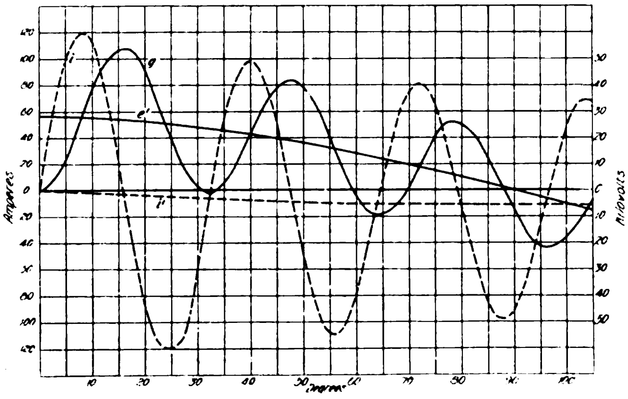

Fig. 4

Thus, in the case of inductance and capacity, the adjustment of the circuit at a change of conditions does not occur gradually, but is effected by a series of oscillations (shown in Fig. 4), during which the energy surges between magnetic and static energy until it is gradually dissipated in the resistance. These oscillations, representing the adjustment of the circuit to the changed conditions, last the longer the greater the inductance and capacity—that is, the greater the amount of energy stored. On the other hand, these oscillations die out the faster the greater the resistance of the circuit: the energy is therefore more rapidly dissipated with a large resistance, and if the latter is sufficiently high, the surge of energy may not develop at all but the energy be dissipated in the resistance during the first transfer from magnetic to static energy, or the reverse.

We may compare a circuit, containing resistance and inductance only, to a pipe line through which water flows; and a circuit containing capacity in addition, may be compared to an open trough. In the water pipe, energy is stored by the momentum of the moving water only. When opening the pipe, the water does not immediately rush out with full velocity, since the water column has first to be set in motion, and this consumes the pressure. When the opening is reduced, the flow does not fall off immediately, because the momentum of the moving water column (the magnetic field) supplies sufficient pressure at the first moment to keep up the same flow of water through the reduced opening. This momentum gradually gives off its energy, and the water slows down to normal conditions of pressure and flow, corresponding to the reduced opening. If we suddenly close the opening and stop the flow, the pipe is liable to burst, just as the insulation of an inductive circuit is liable to be punctured if the circuit is abruptly opened, and the current stopped.

If, in an open trough or canal, we suddenly open the gates, the water rushes in at full head (the short circuit current), and fills the trough. Due to its momentum (the magnetic energy), it continues to flow, and so raises the water level above the normal (overcharges the capacity), to twice its height before it stops, if there is no frictional resistance; the current then rushes out again, empties the trough, rushes in again, and thus in a number of oscillations, or waves, gradually comes to rest at normal height and normal current. If, however, the resistance is very high, due to a long and narrow channel, the water never reaches such velocities when filling it, as to raise the level beyond normal; that is, no return flow or oscillations occur, just as no oscillations appear in an electric circuit of very high resistance.

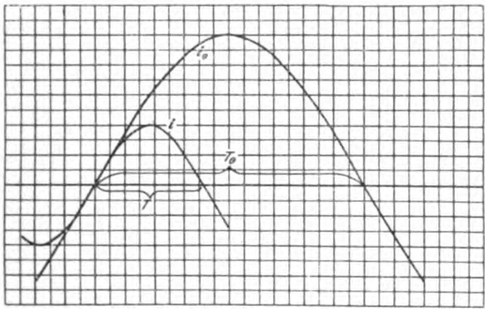

Fig. 5

When closing a circuit containing inductance and capacity, the capacity during the first moment acts as a short circuit on the supply voltage; that is, the current i rises at the same rate as the short circuit current i_0 (Fig. 5). This current i, however, does not last throughout the whole period of impressed e.m.f., as does the short circuit current i_0, but stops when the condenser is charged; *i. e.*, when it has stored the energy $\frac{e^2C}{2}$. The condenser then discharges again with current i, and when fully discharged, it has given off all its energy to the current, where it is stored as magnetic energy $\frac{i^2L}{2}$. During the oscillations, the static energy must therefore be equal to the magnetic energy; or

$$\frac{e^2C}{2} = \frac{i^2L}{2} \qquad (1)$$

and the current i rises at the same rate as the short circuit current i_0; hence we have, from Fig. 5

$$\frac{i}{i_0} = \frac{T}{T_0}$$

where T = duration of one half wave of the oscillation, and T_0 = duration of one-half wave of the supply voltage; that is

$$\frac{T}{T_0} = \frac{N_0}{N}, \text{ and thus}$$

$$\frac{i}{i_0} = \frac{N_0}{N} \qquad (2)$$

where N_0 = impressed frequency, and N = frequency of oscillation.

The short circuit current of a system, when neglecting resistance, is, however

$$i_0 = \frac{e}{x} = \frac{e}{2\pi N_0 L} \qquad (3)$$

where $x = 2\pi\, N_0 L$ = reactance:

Hence

$$\frac{i_0}{e} = \frac{1}{2\pi N_0 L}$$

and, by combining this with (2)

$$\frac{i}{e} = \frac{1}{2\pi N L} \qquad (4)$$

From (1) it follows that:—

$$\left(\frac{i}{e}\right)^2 = \frac{C}{L} \qquad (6)$$

hence, by substituting (5) in (4) we get:—

$$N = \frac{1}{2\pi\sqrt{LC}} \qquad (6)$$

= frequency of oscillations.

In a long distance transmission line, with distributed capacity and inductance, due to the difference in phase of the different parts of the line, the resultant capacity and inductance, or the arithmetical means of a half cycle, $\frac{2}{\pi}$ C and $\frac{2}{\pi}$ L, have to be used instead of C and L, and equation (6) then assumes the form:

$$N=\frac{1}{4\sqrt{LC}} \tag{7}$$

we have then, from (4):

$$i=e\sqrt{\frac{C}{L}} \tag{8}$$

or:

$$e=i\sqrt{\frac{L}{C}} \tag{9}$$

the equations relating the transient term of current, i, and of e.m.f., e.

That is: if $e=e_0$ is the supply voltage, the oscillating charging current is given by (8) as:—

$$i=e_0\sqrt{\frac{C}{L}}$$

If i_0 = the instantaneous value of the short circuit current, and the short circuit is suddenly ruptured, thus causing an oscillation, the e.m.f. of this oscillation is given by (9) as:—

$$e=i_0\sqrt{\frac{L}{C}}$$

or, by (3):

$$e=\frac{e_0}{x}\sqrt{\frac{L}{C}}=\frac{e_0}{2\pi N_0\sqrt{LC}}$$

where e_0 = impressed e.m.f., N_0 = main frequency.

The latter e.m.f. may reach enormous values.

It thus follows, that whenever in an electric circuit a change of circuit conditions takes place, the corresponding adjustment of the stored energy of the circuit occurs by a transient term which, if the circuit can store energy in one form only, is a gradual approach from the previous to the changed conditions. If, however, the circuit can store energy in two different forms, magnetically and statically, the transient term usually consists of a series of oscillations, which gradually die out by the dissipation of their energy in the resistance of the circuit.

Some causes of such change of circuit conditions are:

1. Change of load, as starting the circuit, opening it, or short circuiting it.
2. Abnormal currents entering the circuit, as by electro-magnetic induction from a lightning flash parallel to the circuit; or a short circuit on a parallel line; or abnormal voltages entering it, as by static induction from the clouds.
3. Sudden changes of static charge on the circuit, as by spark discharges, or arcs from the circuit to the ground or to other conductors.

The latter class of disturbances has the tendency to become recurrent, since the spark discharge from the circuit is usually the result of a defect in its insulation, and during the oscillations caused by it, the voltage of the circuit doubles, and at this increased voltage a second discharge takes place, etc.; thus the disturbance may continue indefinitely.

Some of the more interesting cases of such transient phenomena will be discussed in a later paper.

OPEN VERSUS ENCLOSED AND SEMI-ENCLOSED CAR LIGHTING*

By G. H. Stickney

Representing W. D'A Ryan

The primary purpose of lighting a car is to provide for the comfort of the passengers, and it is with this end in view that the skill and experience of illuminating engineers are enlisted. Considerable attention has been given recently to the subject, and numerous suggestions and changes have been made, but there still seems to be room for improvement.

In taking up any lighting problem, the physiological aspect should never be lost sight of, for it is necessary to consider the eyes of the people who are using the light. Outside of the questions of ventilation and heating, the only way in which the lighting affects the passengers is through their eyes. Perhaps the most common defect in car lighting is the glaring effect of lights of high intrinsic brilliancy. This is particularly noticeable to a passenger when he is occupying one of the rear seats, so that there is a line of lights in front of him which comes within his range of vision and shines in his eyes. Of course, the low decking of the car makes it necessary to locate the lights relatively low, so that the lamp is unavoidably within sight. The light enters the eye at such an angle that the physical properties of the eye render it incapable of protecting itself. This point is illustrated by snow blindness, which affects the eye, not because the intensity of the light is stronger than the light which comes from above, but because it enters the eye from a direction at which the eye is powerless to shield the optic nerve.

Now, the intrinsic brilliancy of a light source may be defined as the intensity of the light divided by the area of the source; that is, if we have two lights of equal intensity, that one which has the smaller area is the more brilliant, and is the one which will produce the greater tiring effect on the eyes. If we can enlarge the area of the light source, and without changing its volume, make the light come from a large surface, you can see immediately that it will be much easier on the eyes. If this dispersion be carried far enough, one can even look directly into the light without being nearly so much affected as by a casual glance at a light of great intrinsic brilliancy. Fortunately, increasing the source of light produces several other improvements. It improves the diffusion of the light around bodies, cuts down harsh shadows, and aids in making distribution over all points equal in intensity. It is very unpleasant, when reading, to have the lights situated so that the shadow of one's head, for instance, comes directly on the page. I think passengers have been troubled with this defect quite seriously.

Now, to come to the question of proper intensity. In nearly all illuminating engineering problems we find quite a wide range of variation in opinions among those who are using the light, as to the intensity of light that is necessary in order to perform a certain work, or to see with a certain degree of fineness. Outside of the requirements of different conditions, this variation of opinion necessitates our making an extended study of the subject in order to determine an intensity which is a compromise between the desirability of strong illumination and the matter of cost. For economic reasons the intensity of artificial illumination almost always falls far below that of daylight. In car lighting there is a demand for quite a variation of intensity in a single car; for instance, a person who is reading requires considerable intensity of illumination, while another person, who is whiling away his time and trying to sleep or rest, would prefer a relatively low intensity. So, outside of the cost of illumination, we desire to secure easy reading with as low an intensity of light as possible. This condition is also facilitated by properly diffusing the light.

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* A paper read before the Western Railway Club, Chicago, on Sept. 17, 1907.

About a year and a half ago, in connection with lighting one of the large stations of the country, Mr. Ryan ran a series of experiments for one of the railroads, in which he lighted a high room by arc lamps suspended in the top of the room, and also by arc lamps concealed so as to reflect the light on the roof, and then downwards into the room, no lamps in this case being visible. Of course, the latter method was a great deal more extravagant of light, but a committee of railroad officials who looked at the installation decided that the diffused illumination, which was only two-thirds as intense as the direct illumination, permitted them to see objects and to read more easily than the direct illumination, while the general effect was much more pleasant.

Another quality of illumination which should be considered in connection with the eyes is the color of the light. It is not absolutely essential that the light should be perfectly white, or daylight in color, but it should approximate this color as nearly as possible; and if there is to be a variation, it should be in the direction of the warm colors; such as yellow, for instance, to which people are accustomed, both in their ordinary indoor lighting and in the waning of daylight. The eye has been developed to its present state through the action of daylight, and to some extent through the action of artificial lights to which the people have been habituated, and is therefore better able to perform its functions by such lights. An excessive distortion of color should always be avoided -- you could hardly expect the public to tolerate an extreme monochromatic light.

In selecting an illuminant for a particular lighting problem we have found it desirable to make the power and capacity of the lighting unit bear some definite relation to the area to be illuminated. In a high room of considerable size we would use a large powerful unit, and in a small low room a correspondingly smaller unit. In cases of armory lighting, as an example, we make a practice of grouping several arc lights together to form a single unit, while in order to obtain even illumination in a moderate sized room, the lighting unit must be relatively small. So of all the electric lamps available, the incandescent lamp lends itself most readily to car lighting.

Within the past few years there has been some very extensive developments going on in the construction of incandescent lamps; new materials have been discovered which have made it possible to increase the efficiency of an incandescent lamp very considerably. Up to about the present time it has been necessary to use a carbon filament which required the expenditure of from three to four watts for every candle power, whereas it may soon be possible to use a tungsten filament consuming approximately 1½ watts per candle power; that is, per horizontal candle power. This increased efficiency will be of great aid to all classes of illumination where the incandescent lamp is applicable. The tungsten lamp is particularly adapted to low voltage; in other words, the electrical characteristics of this lamp are such that it can be manufactured more easily for voltages of from 20 to 30, than for 110 volts, the latter being the voltage at which the ordinary incandescents are run. To produce the proper electrical resistance, the relation between the length and the diameter of the filament is the determining factor. The hardest thing that we have had to overcome in constructing tungsten lamps has been the brittleness of the material, and for this reason the short, heavy filaments are the most substantial and suitable for car lighting work.

The great point of advantage of the tungsten lamp is its high efficiency as compared to ordinary incandescent lamps. This is due to the fact that it is possible to run tungsten at a higher temperature than any other material which has yet been available for the manufacture of filaments. If carbon, for instance, were run at this temperature the carbon would evaporate away from the filament, and in a short time the filament would burn out at some point and the lamp would be rendered useless.

Tungsten is a metal which has a lower resistance than carbon, so that a longer and more slender filament is required for the same voltage. In most of these lamps there are two filaments connected in series, each of which is about the size of an ordinary looped incandescent filament for 110 volt circuit; while the tungsten lamps are intended for only 30 volts. Another advantage of the tungsten lamp is that with a slight increase of voltage the temperature does not increase so rapidly as with the carbon lamp, and hence it is not so liable to be burned out by variations in voltage. The explanation of the relation between temperature and efficiency of lamps may be interesting. When we heat a solid material, for instance a lamp filament, up to a certain temperature, no light rays are given off. As we increase this temperature, we come to a point at which a very dull red ray is emitted, and the efficiency is then very low. As we increase the temperature still further, the material becomes brighter and brighter, the color becoming first yellow and then white. With increasing temperature, the percentage of useful light rays increases very rapidly. We have not as yet been able to produce pure white light in any incandescent lamp without cutting down the life of the filament to such an extent that the cost of replacement becomes too great for ordinary commercial conditions. The tungsten lamp, however, approaches more nearly to this ideal, and at the same time shows a correspondingly higher efficiency. In the electric arc it has been possible to produce practically a white light, because here carbon is maintained at the boiling point. As the electrode used is comparatively inexpensive, it can be allowed to boil away and be replaced without excessive expense. The electric arc, however, is not adapted to the small units we desire to use for car lighting.

Another point in connection with the incandescent lamp is the question of whether clear or frosted bulbs should be used. The light from a frosted lamp is undoubtedly much easier on the eye than that from a clear lamp, when run without a protecting shade, but the frosted lamp falls off in candle power much more rapidly than a clear lamp, with or without an outer shade. This subject has been worked out theoretically and practically, and a number of papers have been written on the subject, but we have found it best to use a clear incandescent lamp and protect the eyes by means of a separate shade.

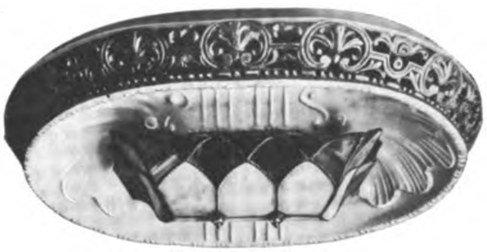
Fig. 1. Three-light, Train-Lighting Ceiling Diffuser

Mr. Ryan's car lighting fixture consists of a steel diffusing screen placed above a row of incandescent lamps, the steel being finished with a white enamel, so as to give a highly efficient reflecting and diffusing surface. This design renders the lamp, to a large extent, independent of the finish of the car, whether this be dark or light, and at the same time permits enough light to fall on the deck of the car to prevent its appearing dark or gloomy. Beneath the row of lamps is placed a long trough shaped shade of art glass. The purpose of this is to cut off the direct light of the lamps from the eyes of the passengers, and to reduce the intrinsic brilliancy, in order to conform to the conditions which we have previously outlined. This form of reflector provides a large area for the source with a low intrinsic brilliancy, so that passengers may sit in a car without experiencing the tiring and even injurious effects of a harsh lighting. It also provides for an even distribution of light throughout the car, so that no seats have advantages over other seats, and harsh and disagreeable shadows are eliminated. In constructing the reflector, all parts are mounted upon a light metal framework, which is attached to the deck of the car. The ornamental casting around the diffusing surface finishes off the reflector and gives it a neat appearance, and also prevents an open space existing in which the dust and dirt would accumulate and spoil the appearance of the installation. The diffuser is of stamped steel and is made in sections, so that the size of the unit may be varied for different conditions; for instance, in the body of the car a long reflector may be used varying anywhere from about two or three feet up to the entire length of the car. This design was made to provide flexibility, in anticipation of the likelihood that it might be desirable at some time to use one continuous reflector for lighting the car. The designs, as adapted at present, are merely the oval and the oblong shapes. The shade is a trough of art glass, which conceals from view the separate individual lamps. When it is desired to turn down the light, or reduce the intensity, part of the lamps may be cut out without its being noticeable that some of the lamps are not lighted. Each fixture is just one general source of illumination, whether all or only part of the lamps are in service. The dimensions of the light reflector are 48 inches long by 20 inches wide, and 10 inches deep. The weight of the reflector as constructed is about 37 or 38 pounds. The advantages of the reflector may best be stated as follows:

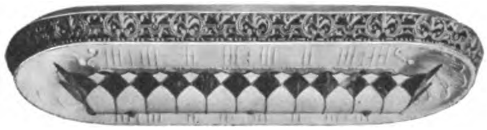

Fig. 2. Six-light, Train-Lighting Ceiling Diffuser

1. Softness and general diffusion of light eliminating strong shadows.

2. Clear bulbs can be used, thereby materially increasing the life of the lamps and diminishing the initial and maintenance cost. It is a well-known fact that the difference in useful life between a clear and a frosted lamp is somewhere between 30 and 40 per cent. On railway trains, particularly, frosted lamps accumulate a very large amount of smoke and dirt, so that the use of a clear bulb is a decided advantage which cannot be obtained by any other form of illumination with which I am personally familiar. For example, if the lamps are enclosed in a prism glass globe, aside from the usual disadvantages of this glass, you have a high intrinsic brilliancy in streaks.

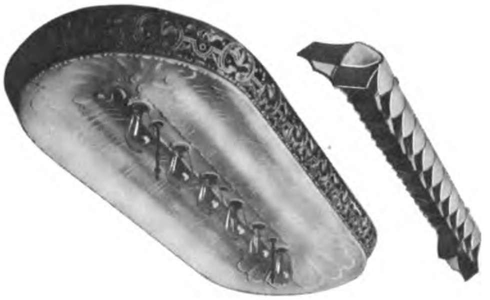

Fig. 3. Six-light, Train-Lighting Ceiling Diffuser, with shade removed showing lamps and diffusing screen

3. The apparatus can be made attractive in appearance, with a possible saving on first cost as compared with some of the quite elaborate fixtures now used in Pullman cars.

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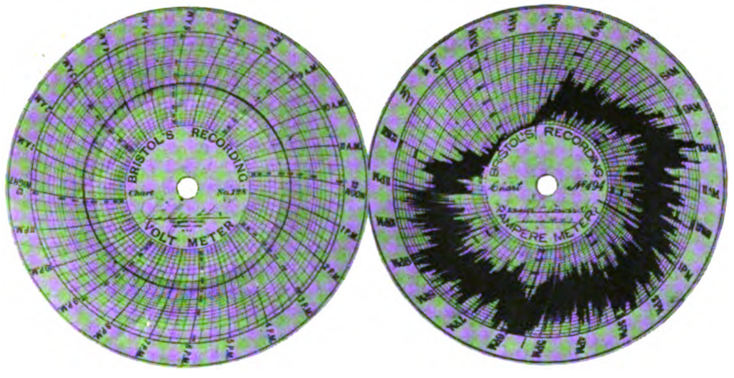

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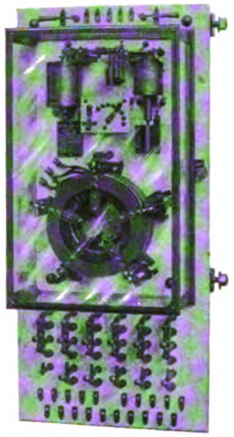

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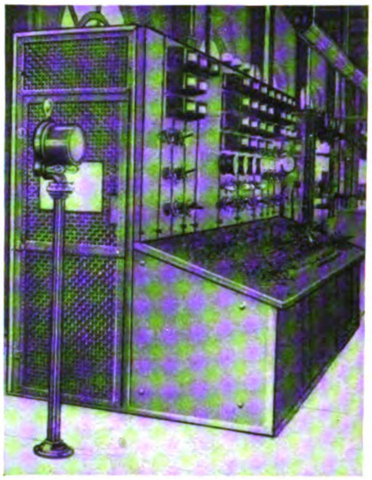

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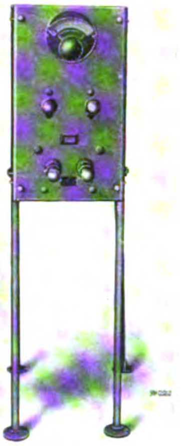

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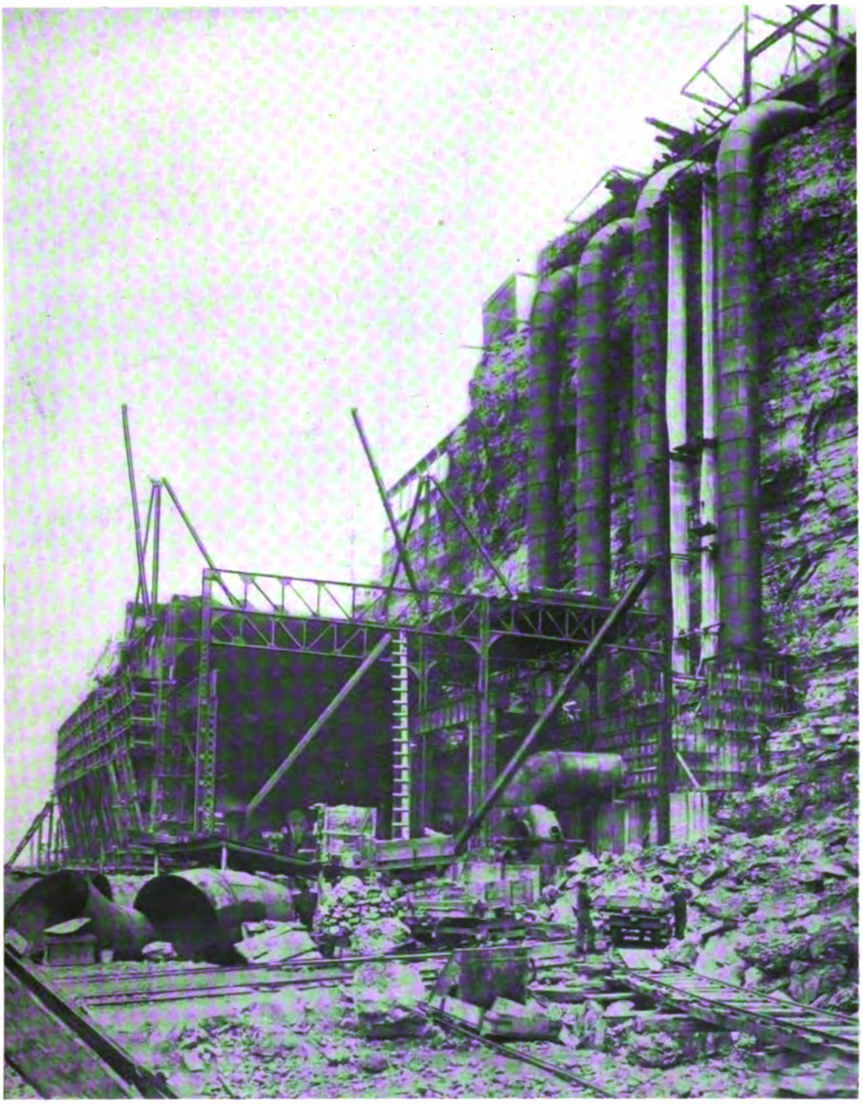
JANUARY, 1908



Station No. 3, Niagara Falls Hydraulic Power & Mfg. Co., in Process of Erection

(See page 51)

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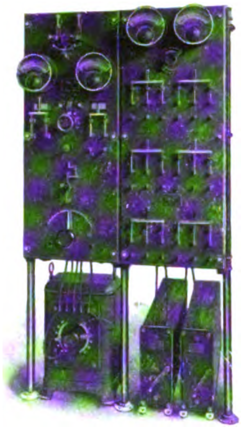

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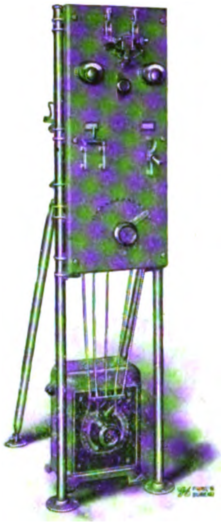

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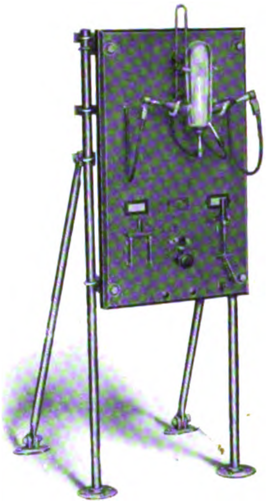

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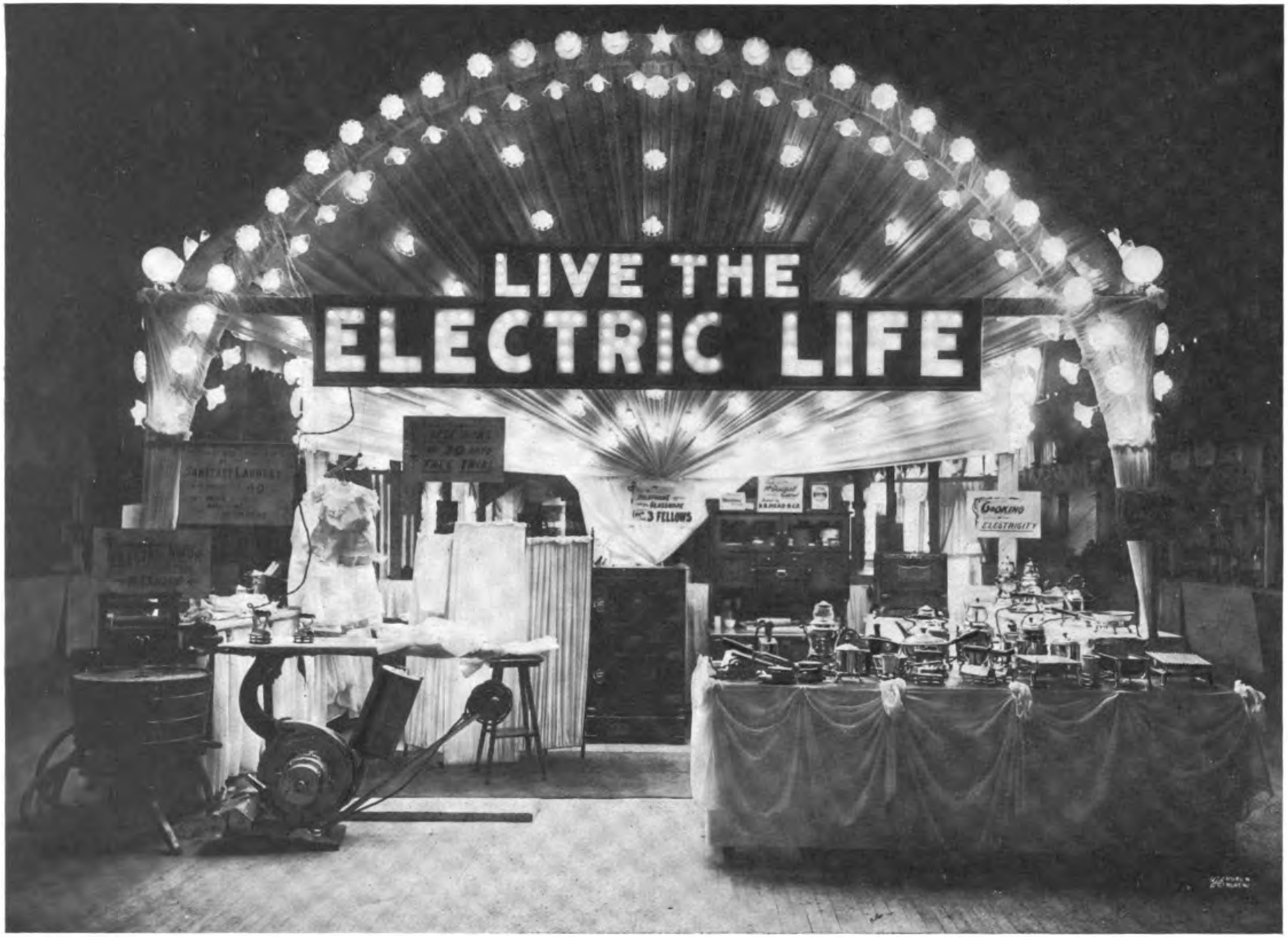

Booth at Pure Food Show, Rockford Edison Company, Rockford, Ill.

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GENERAL ELECTRIC REVIEW

THE NIAGARA FALLS HYDRAULIC POWER & MANUFACTURING COMPANY*

By Geo. R. Shepard

The design of a power station is influenced, first of all, by the local conditions, and that design which develops the water power and gets it from the power house in the simplest manner is the most successful development, from all points of view. As engineers of the company, our endeavor has been to do this, regardless of appearances to some extent.

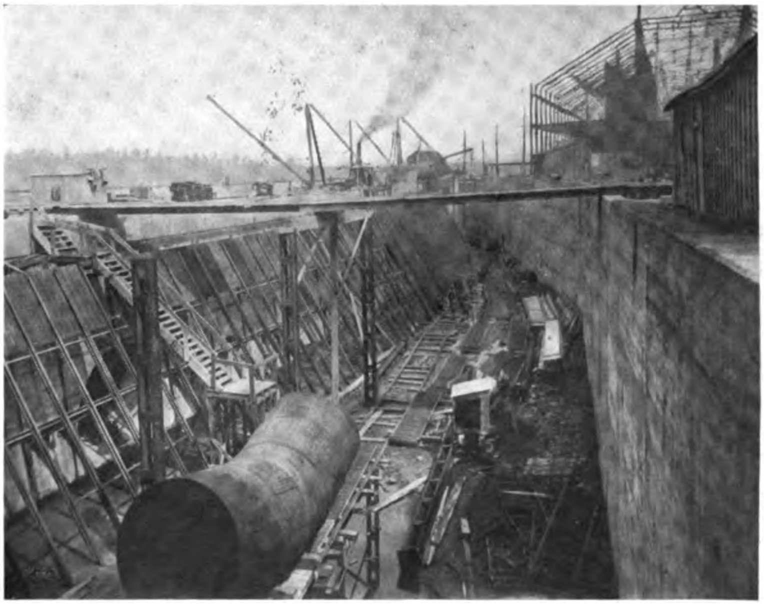

Fig. 1. Forebay of Station No. 3 while Building

The original plant of the company, which we call our No. 2 plant, was begun in 1895 and finished in 1900. There are several points regarding this plant of which I wish to speak, particularly the ones which illustrate what should not be done in power house construction. The water for this plant comes through two raceways, running down into the forebay. Several pipes leave the forebay at an elevation of about 550 ft., and run over the edge of the cliff into the station, which is at an elevation of 340 ft., giving approximately 210 ft. effective head on the wheels. These pipes run the entire length of the station in a subway. The wheels are set directly above the pipes, and there is a separate opening from the pipe into each wheel, which is a very bad arrangement. The really proper method is to have a separate pipe for each unit.

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* Lecture delivered before the Schenectady Section A.I.E.E. November 21, 1907.

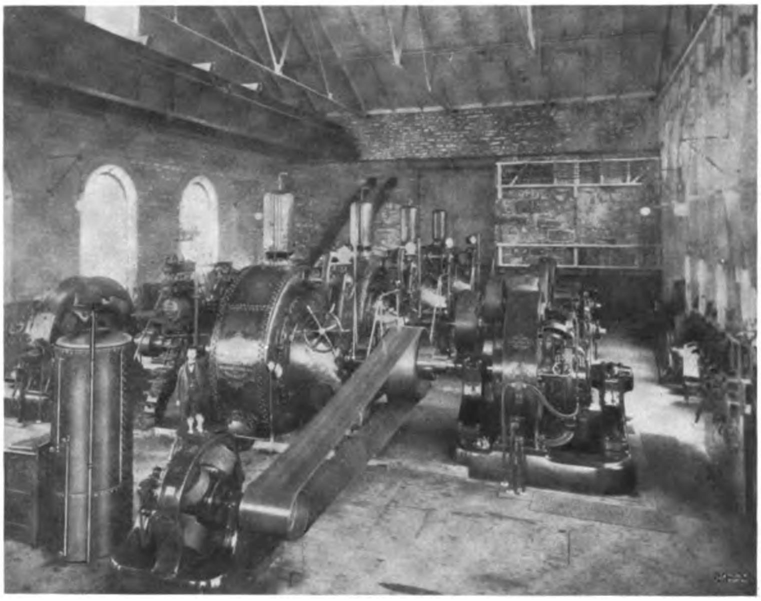

Fig. 2. Generator Room, Station No. 2

The prime feature, from the hydraulic point of view of the power station, is to see that the water gets to the water wheels and away again by turning the fewest possible corners, and any turns in the direction of flow of the water should be as moderate as possible. These corners mean a loss of efficiency in the water power, and in our first station I presume we lose in this way between five and ten per cent. of the available power.

In the forebay of our new station, which was built this summer, the concrete has been curved where the water enters the mouth of the penstocks, forming a bell-mouth opening. This is the proper design for a place of this kind, as these bell-mouths allow the water to have a uniformly increasing velocity from the entrance to the pipe proper; that is to say, a uniform acceleration from the bay into the pipe; which, of course, means we lose less head than in any other way. This station brings out another feature which was neglected in the first plants; that is, the depth of the forebay from the top of the water. This is about 15 ft. in the old plant, and 30 ft. in the new. We found in the old station, at times of very low water—and we do have low water at Niagara, as well as at other places—that there was a tendency to suck air into the penstocks, which was very injurious to the pipes, as the air set up vibrations, and at times we have had grave fears for their safety. In each of these new pipes, which are 9 ft. in diameter, we have a sluice-gate, and around this sluice-gate there is an 18 in. by-pass valve. The penstocks are filled while the sluice-gates are closed, and the gates are then raised with pressure on both sides.

This is important in the design of a power house under any great head, as it is extremely difficult to get valves to operate satisfactorily under these conditions; but by placing them at the top of the penstock we can operate them under a head of 25 ft., and in case of necessity they can be closed under full head. This would be extremely difficult to do if they were under a head of some 205 or 210 ft. When for any reason we want to get the penstocks dry, we have a drainage system which takes care of any water which may leak through the valves. We have found that the least bit of water falling through the vertical height of these pipes, 150 ft. or more, produces a sort of pump action, forcing cold air and spray into the wheels and out through the man-holes, so it is almost impossible to get into the wheels to make repairs, or do cleaning. It is essential, for the proper maintenance of the plant, to be able to get the wheels absolutely dry, and on this account the drainage system was established. A slot is embedded in the concrete, and between this slot and a guide-piece on each side, we drop two 9 ft. stop-gates, which shut off the water sufficiently to enable us to get at the sluice gate inside. This is only used in cases of emergency.

The racks or screens which take the sticks and debris from the water, are made of bars ⅜ in. x 3 in., spaced with about 2 in. centers. The sections from the bottom to within about 5 ft. of the top of the water are made removable, so that they can be pulled out at any time. This has been found necessary on account of the slush ice which we have in certain seasons of the year, notably in the early winter, just after the water reaches freezing temperature. Water at that time is full of slush ice, which adheres to the bars; and in an hour or so, if not watched and prevented, it would close up the passages between the bars, and cut off the water from the station. We keep a record of the temperature of the water and air from day to day, and have plotted a curve of water temperature, running through the entire year. By this curve we are able to determine, about two days in advance, when the water will reach 32 degrees, and when we will have slush ice. We keep our eye on this curve, and when it reaches the proper point we pull out enough rack sections to give a clear passage of the water and ice, and await developments. We have had this slush ice within twenty-four hours of pulling out the bars, and then again a week has passed before it came, but this has been the greatest length of time, which shows the efficacy of the curve. We leave the racks in as long as possible, to prevent sticks and debris from getting into the wheels, and this curve enables us to determine pretty closely the proper time to pull them out.

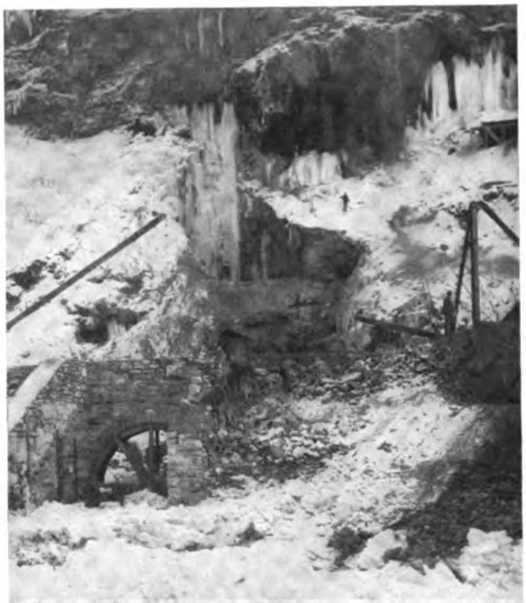

Fig. 3. Site of Station No. 2, Showing Difficulties of Winter Construction Work at Niagara

The forebay proper is on the outside of the racks, and a space between the racks and the entrance to the penstocks is necessary for the water to quiet down after it has passed through the narrow openings of the racks. From a velocity of 1½ ft. per second at the racks, it increases to its maximum, and when it reaches the wheels, is running at a velocity of 10 ft. per second. This increase is made uniformly in the curved opening.

A vent pipe running from the main pipe up to the top of the wall is extremely useful. It allows the air to enter the pipe in case of sudden shut-down, or when draining the water from the pipe. In our original installation we had a 9 ft. pipe under 125 ft. head, in which there was a somewhat similar opening about 6 in. in diameter. On one occasion we had to shut down very suddenly, and neglected to see whether the vent pipe was in operation. As a matter of fact, it was frozen up, the penstock collapsed, and we had to put in 50 ft. of new pipe. You can therefore see the importance of the air vent.

Turning our attention to the ice in the water, we started in with the theory that we ought to get water into the canal without any ice. After several years we made up our minds this could not be done, and the next question was, how to get rid of it. The water comes in in a direction parallel to a boom, which is simply a steel frame running across the forebay, and extending about 10 ft. below the surface of the water. On the extreme left of this boom we have a gate leading into a raceway off at one side. This gate is lowered, instead of being raised, allowing the water to fall over the top of the gate and creating a surface current. The floating ice naturally follows this surface current, is spilled over the top of the gate and runs off. The water goes in underneath the steel boom and flows into the wheels. This arrangement was worked out for our No. 2 station several years ago. In that plant we found it difficult to run the ice off without its jamming in our long raceways. It jammed continually, until our Superintendent conceived the idea of bringing his tug, which was laid up for the winter, to the mouth of the raceway, and there making it fast. The propeller was started up, and acted as a sort of pusher, and we had no more trouble. The next winter we put a propeller in the raceway and

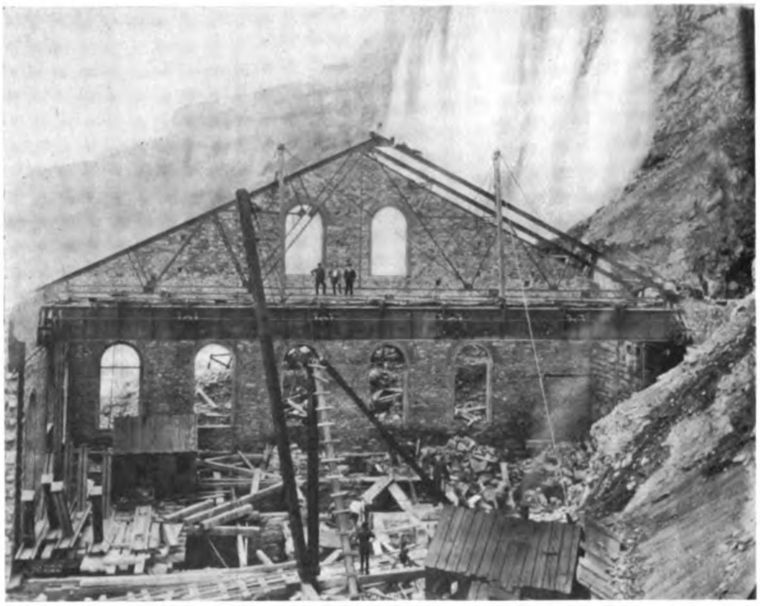

Fig. 4. Station No. 2 while Building

connected it to a motor, and there has been no further ice clogging, the propeller doing the work of about 30 men.

To protect the power house of our No. 2 station from the ice in the river, we built a wall 5 ft. thick outside of the end wall of the power house, and have found this an ample protection. The masses of ice which form here every winter reach almost to the top of the bank—something over 100 ft. of solid ice, which lasts usually until about the first of June.

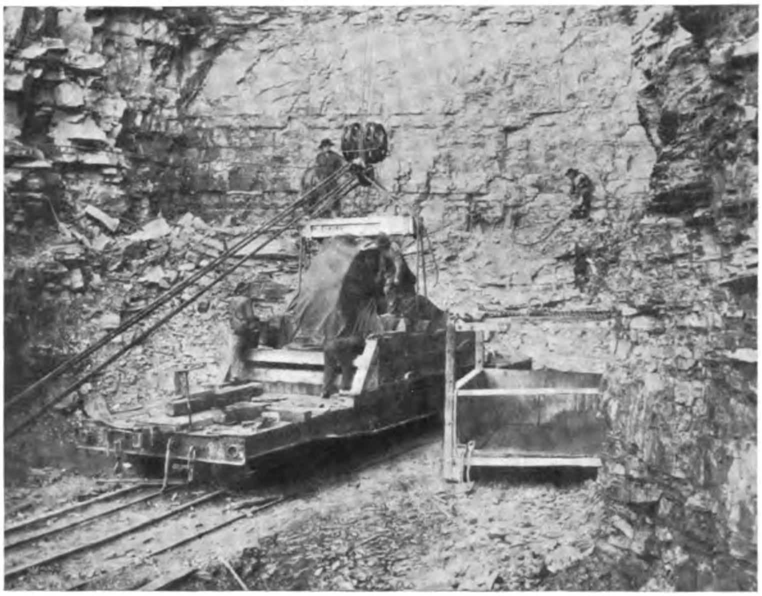

Fig. 5. Landing an Armature and Car from Cliff Above

From the face of the cliff to the water is a space 150 ft. wide on which there was debris of every kind, which consisted of boulders of all sizes, and other material dumped over the bank from time to time. We took all this loose stuff out with an hydraulic jet. Water was brought down from the top of the bank in a pipe 12 in. in diameter, the lower end of which was fitted with a nozzle having a four inch opening, and this was turned onto the bank. I think this is about the cheapest form of excavation ever devised. We figured that it cost $1000.00 to install this apparatus, and by running it after working hours, by the time it was too dark on summer days we found this removed anywhere from six to seven hundred cubic yards per day. Figuring $5.00 for operating expenses, the cost was about one cent a yard, which is very cheap excavating.

Our No. 3 station was built of concrete, with the exception of the wall facing the river, which the Commission, appointed by Secretary Taft, insisted on having built of rubble masonry to match the bank. The architect's explanation of this was that a concrete building decreases the apparent height of the cliff, and this is extremely important to preserve—therefore the rubble masonry was used.

We have a traveling crane, of a capacity of 65 tons, located on the top of the cliff, and all material shipped in is lifted directly from the cars, carried over and dropped below the bank, all in one operation.

Fig. 5 illustrates part of quite an interesting operation. It shows the landing of the armature of one of our big generators at the bottom of the cliff, by means of our 65-ton crane. These armatures arrived from the General Electric Co. on General Electric cars, and they were very well put on. The track shown runs some 450 ft. from the base of the cliff to the part of the station where these generators were to be installed, and our superintendent conceived the idea of lowering the armature, car and all, without unloading. We picked up the whole thing, and after landing it below, ran the car into the station, unloaded the armature, and then sent the car back. I might add that the car checker of the railroad appeared, and not finding the car, nearly had nervous prostration looking for it. We took particular pains to take it back when he was not around.

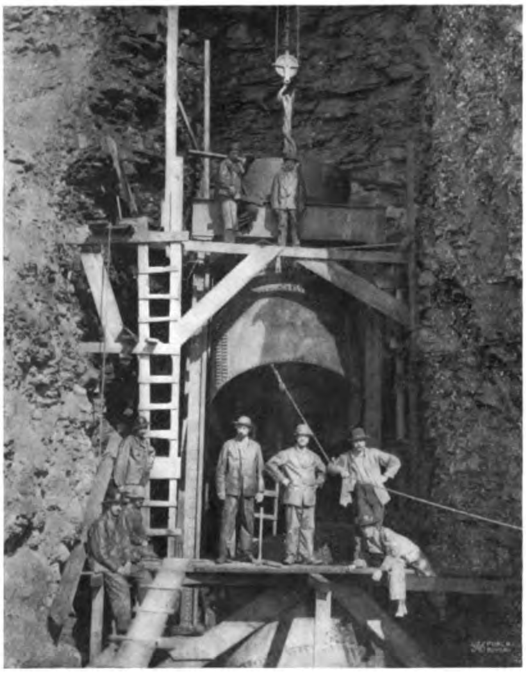

Fig. 6. Penstock Construction

Fig. 6 is interesting only in showing penstock construction. It shows the notch cut in the bank, and the penstock hung up on a steel frame. It is difficult to set this steel frame properly, and even more difficult to secure the penstock to the frame. On account of the water rusting the pipe rapidly, we found it necessary this summer to encase the pipe in concrete, making a shell about 12 in. thick, completely enclosing it. We have discovered that concrete is an absolute protection for iron; in fact, it not only protects the iron, but when put around rusted iron, this will clean up and stay clean. We removed some concrete from iron which had been enclosed for perhaps five years, and although the concrete was put on when the iron was rusty, the latter was as bright as if it had been polished.

The illustration on the front page of the cover shows Station No. 3 in process of erection, one penstock completed, and the other partly so. These penstocks were shipped in sections of about 30 ft., which were lined up and then riveted with the little riveting platform shown in the cut, which was made to go around the pipe, and slide up and down. The power house itself is in two sections—the water wheel or hydraulic compartment, and the generator or electrical compartment. It is almost impossible to keep our water wheels dry, and we have had leaks develop of more or less magnitude, which have been disastrous to the generators right next to the water wheels. For this reason we put in a concrete wall, provided with a hole for the shaft, between the water wheel and generator, and in case anything goes wrong in the water-wheel room, the water cannot get to the generators. We have had a demonstration of the efficacy of this arrangement, although the station has not been in operation for more than two or three months.

The two white streaks running up between the penstocks are the aluminum bus-bars which carry the current from the station to the top of the bank. The Aluminum Company of America expects to take about 40,000 h.p. through these bus-bars, and unless I am mistaken, that figures roughly about 40,000 amperes, at their voltage. There is quite a perceptible field about these bars when they are in operation, but we have experienced no trouble from electrolysis.

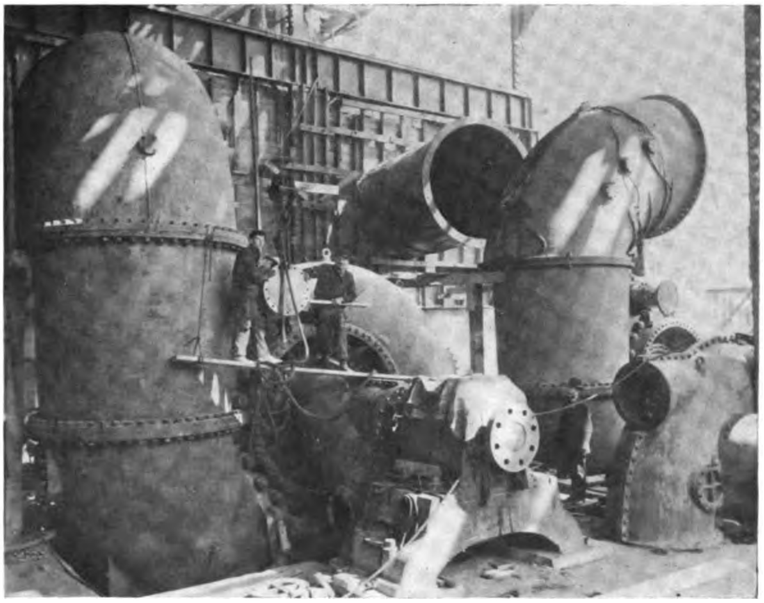

Fig. 7. Installing Water Wheels in Station No. 3

The bus-bars run up over the forebay on an overhead construction directly into the Aluminum Company's building. The current is all turned into heat, and the best kind of ventilation is necessary in order that the men may live at all in the pot room.

Fig. 7 shows the water wheels in our new station. The penstock coming in through the wall turns an angle of 90 degrees and runs around in a snail-shell form. The theory of efficiency of a water wheel is that the water shall have as few sharp turns as possible, and that in the runners the velocity shall increase from that of the penstock up to a certain well-defined, fixed percentage of the velocity due to the head. From the wheel it slows down until it finally leaves the draft tubes at a velocity at which it will not eat out the concrete tailrace. This is accomplished by gradually restricting the cross section of the water passages and the runner openings. We are forced to use draft tubes on our wheels, as the extreme variation in the elevation of the lower river is about 20 ft. Our power house floor must therefore be 20 ft. above the low water mark, or about 15 ft. above the mean low water. We usually average 22 ft. of draft tube, and find that this works satisfactorily.

STEAM TURBINES*

By W. L. R. Emmet

The reasons for the existence of the steam turbine are many. One of these is that it is a mechanically simple machine, involving less complicated mechanical elements, and having certain practical features which have made the electric motor great and successful. Another reason is that it works in a field which the reciprocating engine cannot occupy, as it gives us the possibility of good efficiency of action in a wider range of pressure.

The reason why we use steam as a motive fluid is that water is cheap and common. It affords the most available method we have of turning heat into motion. Other fluids than water might be employed, for certain sets of conditions, to make a vapor which could be used instead of steam; it has been proposed to use such other fluids, and this has been done to some extent. It is possible that there are other fluids than steam which would give higher efficiency than steam gives and make possible greater thermal range.

Roughly speaking, the efficiency of a machine depends upon the range of temperature through which it can be worked, and this range with steam is quite small. The upper range of temperature in steam processes is limited by the pressure which is practicable, say 200 lbs. to the square inch, corresponding to a temperature of say 380° F. This temperature is not nearly so high as we might work, but the pressure becomes prohibitive as we go higher. With superheated steam we go up to 700° F., but the superheated process is simply a very small increment upon the other process.

As the steam expands in the engine or turbine, it would, if dry, cool rapidly by expansion; the fact that it is a vapor prevents this, because as it cools it liquifies a part and gives up the latent heat of vaporization, and this action sustains the temperature. Thus temperature and pressure follow a different curve than that which would be followed if steam were gas. Thus we have a natural cycle of operation in every steam process by which the heat carried by the steam, whether dry or superheated, may be turned into energy; and this process bears a certain fundamental relation to a theoretically perfect engine process. If a steam engine were perfect, the possible efficiency of the process, working say from 200 lbs. down to good vacuum, would be 33 per cent., but what we actually realize is some fraction of this. Now this 33 per cent. of the total applies to a certain range of temperature, 370 or 380 degrees F. down to say 100 degrees F., which is what we may call the practical range of operation in a turbine. Of this our engine can recover a certain proportion, and the proportion recovered we call its efficiency. The question of efficiency in engines is one thing, and the question of net output is another. The efficiency of an engine is its ratio of energy recovered to energy available theoretically. If for any reason we work our steam through a less range of temperature, the amount of energy available is less; and although the efficiency may be the same, the net result will be less. This 33 per cent. that I have mentioned is the proportion which the steam cycle within the temperature range bears to the perfect engine working within that temperature range. If we diminish the temperature range, the perfect engine would give less output. We have two elements, one the efficiency, and the other the range of available energy. In order to explain the difference between the reciprocating engine and the turbine, I will say that one of the great advantages of the steam turbine is that it is capable of giving good efficiency, if properly designed, through a wide range of pressure and temperature; whereas the steam engine has mechanical limitations which greatly reduce its effective range. The range of pressure and temperature, within which reciprocating engines are practically comparable with good turbines, is that from ordinary boiler pressure to the atmosphere. Below atmospheric pressure the performance of the reciprocating engine begins to fall away rapidly, and the efficiency for each addition to the range of the cycle becomes less and less; and finally, when we come into the higher degrees of vacuum, the amount of work recovered is very small; whereas in the turbine the efficiency throughout the whole range down to very high degrees of vacuum is practically constant, in fact it is even better in lower ranges where friction losses are less.

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* Lecture delivered before the Schenectady Section A.I.E.E. November 6, 1907.

To get an idea of these possibilities, I will tell you what the available energy in steam amounts to under some different conditions of pressure. In working steam from pressure of 165 lb. absolute down to a 29 in. vacuum, the available energy is 271,000 ft. lb. per pound of steam. If we work to the atmosphere instead of to this vacuum, the energy available amounts to 136,000, which is one-half of the share, so we have used up one-half of our theoretical cycle when we have gone to the atmospheric pressure.

If instead of working to a 29 in. vacuum we worked to one of 24 in., we only use 76 per cent. of the energy which we would have with the 29 in. vacuum. That is, by changing our vacuum from 24 in. to 29 in. we add 33 per cent. to the possible output of the engine. A 24 in. vacuum is about the limit of important gain in the reciprocating engine, it will gain something with a better vacuum than 24 in.—possibly two or three per cent.—but it is practically at the end of its possibilities when it gets to that degree of vacuum. There is a limit to the size of the cylinders and the low pressure valves; and the immense surface exposed, together with high degree of expansion in the steam engine, involves loss through cylinder condensation. The principal difficulty is the weight and bulk of the necessary moving parts. Steam with a 28½ in. vacuum has a volume about 200 times as great as it has at 175 lb. gauge.

The idea of the steam turbine is a very obvious one, and naturally appeals to everybody. It is the simplest form of production of motion from pressure, and was used by the ancients. The whole difficulty has lain in the fact that the velocities to be dealt with were so high. Steam carries so much powe and weighs so little that it attains an enormous velocity when its work is turned into motion. In working steam of 175 lb. gauge down to 28 in. vacuum, it will impart to itself a velocity of about 4100 feet per second. The fastest turbine wheels used by the General Electric Company have a peripheral velocity of 460 ft. per second, only about one-tenth of the maximum velocity of discharging steam. At that velocity of 460 ft. per second, the rim tension in a revolving steel ring amounts to 25,000 lb. per square inch. This is the elastic limit of ordinary steel. You see, even at this very low velocity, (only one-tenth that of the steam), we are near the practical limit of construction.

DeLaval, who built one of the first successful turbines, did not attempt to go further than the application of the simple jet to the single wheel. He designed a wheel with thin edge and thick middle, so proportioned that it could be run up to speeds possibly in the neighborhood of 10,000 ft. per second, and although that speed was not as high as it should be in proportion to the velocity of his jet, he got very good results and made a very clever design to make those results mechanically available.

In the Parsons turbine he has made a drum construction with a great number of buckets, and the steam passes through various rows of stationary and moving blades. In these rows of blades the steam keeps expanding from one to another, and drives the rotor by impact upon the moving blades and reaction from the velocity of discharge from the moving blades.

The difficulty about DeLaval's process is that he cannot use a high enough velocity to get a high efficiency, and using the velocity he does it is hard to get mechanical application. The speed is too high to use without gearing. DeLaval tried to make his turbine with more than one stage, and put his single wheels in several successive stages, dividing up the energy, reducing the velocity in each stage, and bringing it into more conformity with his wheels. The difficulty with this is that the pressure in these stages becomes high. With high pressure he got rotation losses and found he did not gain anything, so he kept to the single wheel.

Parsons had opposite ideas; he took up the multiple arrangement, and the difficulty about his process is that he is dealing with a fluid which at the beginning of his cylinder has one volume per pound, and at the end of the cylinder has a volume two hundred times as great. Since the cylinder turns at the same speed at one end as at the other, and since he wants conformity of speeds at both ends to use the fluid effectively, he is forced to rather extreme dimensions. His buckets at the upper end become extremely small and relatively inefficient, and at the lower end they become abnormally large; so that in order to keep his turbine within the bounds of possibility, he has had to sacrifice a good deal at both ends. Most of the Parsons turbines are deficient in the matter of dimensions in the low pressure end, and are too large at the high pressure end. Before the steam enters the turbine at all it is often largely expanded. It is governed by a throttling process, which reduces the initial pressure.

The idea of Curtis was to make a simple device by which a high velocity steam jet could be made to work more effectively than in the DeLaval simple bucket, and he conceived the idea of making the steam bounce at least three or four times in passing through one element of the turbine; that is, steam taken from the nozzle onto a bucket discharges from the bucket and strikes the stationary member, then to another moving element, and so on, repeating the process. By doing this a great deal is lost by friction, but a considerable proportion of the residual energy is saved and worked a second time.

This fractional abstraction of velocity gives conditions which make a great difference in the matter of mechanical construction, and with relatively simple means we can use these modified velocities, whereas we cannot use the higher ones. Mr. Curtis's first idea was to use three or four, or even more, blades on the same rotor in the same stage, with stationary elements between them; and he expected that the steam would pass through and give up work until it was all gone. Our experience very early convinced me that in this he was expecting too much, and for our second group of turbines, I adopted the two-bucket arrangement,—that is, two buckets to a stage,— and that is what we have confined ourselves to largely in our larger work; in smaller machines we are still using the three-bucket arrangement.

One very important element in the turbine is the question of the friction of the fluid itself. This limited the DeLaval operation in more than one stage; it also limits ours, but to a very much less degree, because we drop the pressure to a considerable extent in our first stage, and after that we have our wheels running at comparatively low pressures. Furthermore, we have built large turbines, and in large turbines the friction is relatively much less.

One of the great advantages of the Curtis type is that it is a multiple stage process in which a number of elements are used. The revolving element has no pressure behind it; the pressure of the chamber in which it operates surrounds it; it is simply blown around as a wind-mill is blown around, without any appreciable thrust. In the Parsons

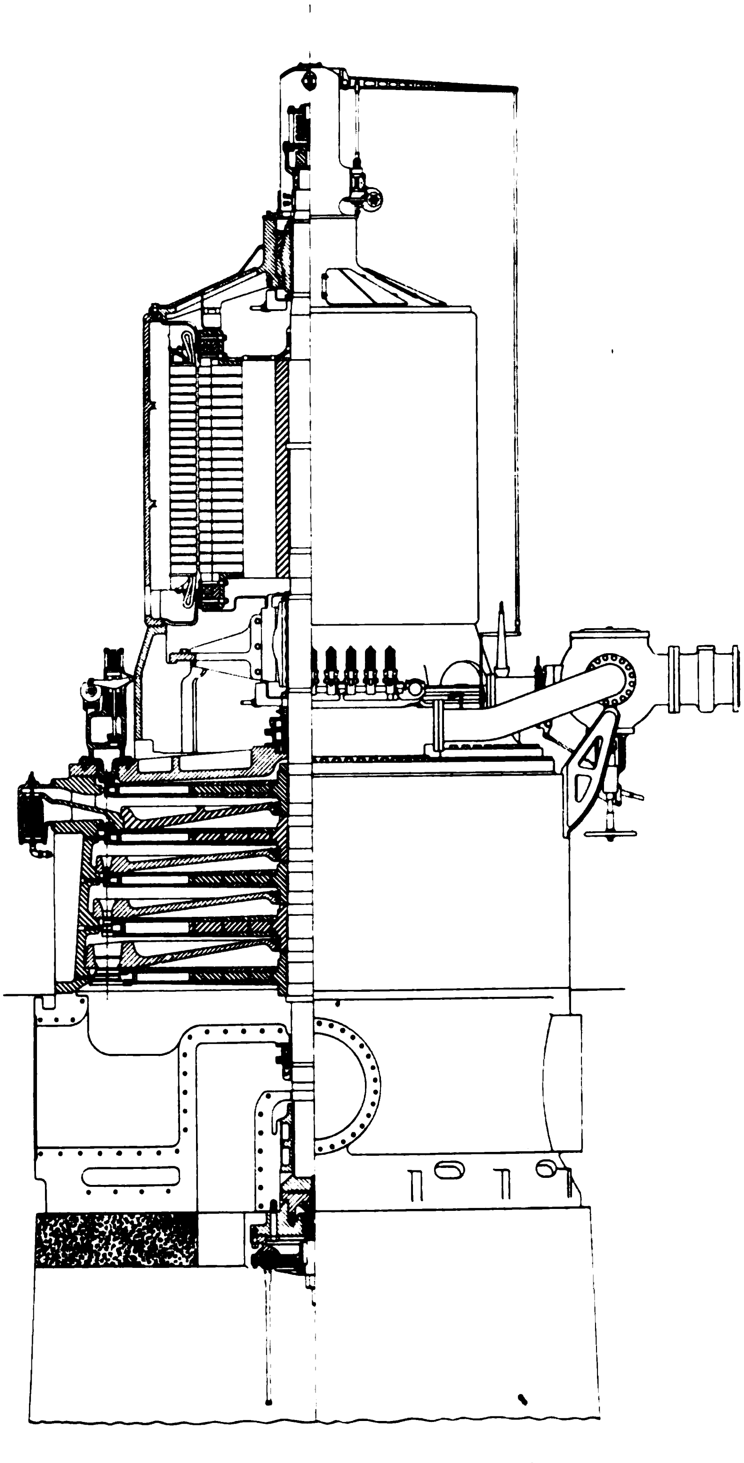


Fig. 1. 14000 Kilowatt Five-stage Curtis Steam Turbine and Generator

turbine, however, the pressure is behind the revolving element, and that pressure must be balanced by a similar revolving element which has no bucket and is simply a dummy that balances and removes the thrust. Now this dummy cannot be made steam-tight; in fact, is must necessarily have a considerable clearance, and that clearance involves a heavy loss, which loss is one of the serious limitations.

This is one of the great features of gain in turbines of the Curtis type. Nobody knows what the distortion of metal is until he begins to build rotating machinery. This is apparent as soon as you revolve the moving element. You cannot run close; you must have large clearances, and this is one of the important features of the whole turbine industry; and one of our great advantages is that we have a type in which we can use large clearances. In large turbines there is no clearance less than ⅛ in. in the axial direction, and radially possibly ¼ in., so they are turning in free space without anything to interfere with them.

The General Electric Company's present form of turbine, in its highest state of development, is shown in Fig. 1. It is a machine which is now rated at 14,000 kw. maximum, and is I believe, the largest that has ever been built, of any kind; it is also the most efficient machine ever built by a very considerable margin. This machine in Chicago has delivered to the switchboard a kw. hour at an expenditure of 12.8 lb. of steam; and that is the equivalent of something like 8¾ lb. per indicated horse-power. Its performance represents not only a very high efficiency of action, but very high range of action, the machine operating from 175 lb. down to a vacuum of 29 in. Other turbines have given as large a per cent. of the theoretical possibility, but no machine has ever given so large an output per pound of steam, and the reason is that this machine is both efficient and designed for a wide range of usefulness; whereas other machines, while efficient, are not suited for so wide a range.

Other machines which have been made by the General Electric Company, are almost equally efficient, and the 5000 kw. unit which has been tested in Boston showed only 0.3 pounds difference in efficiency from the unit in Chicago. All the smaller units, 1000 and 500, show satisfactory efficiencies for their size. These large turbines are five-stage machines, with very deep buckets in the last stage. The smaller machines are four-stage, very small and simple, yet very efficient.

One of the great problems in connection with the turbine industry has been the building of the generators, principally because there has been so much of it to do within a short space of time. An electrical design is something on which it is particularly desirable to have data and experience. It is very hard to foresee electrical conditions, particularly thermal conditions, eddy currents, mechanical strains, effects of vibrations, and other things. In generators for high-speed machinery, centrifugal strains are extreme, and since they are made up of copper and iron, it is necessary to devise all sorts of means for holding the copper and all parts together. The copper, under such centrifugal strains as here exist, will, if unsupported, flow almost like putty; it has to be bound, held and confined by strong steel structures in order to make it stay in place, and all this has to be taken care of in the rotating element. Furthermore, the machine, while highly efficient as most of the General Electric Company's generators are, involves losses like

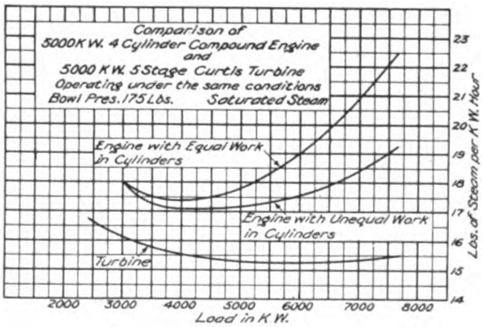


Fig. 2. Curves of Steam Consumption of Curtis Turbine and Reciprocating Engine

other electrical machines—possibly 3½ per cent. in a machine like this 14,000 kw. turbine unit I have mentioned. Three and one-half per cent. of 14,000 kw. is a lot of power and represents a great deal of heat. I may roughly say that the heat represented by the losses in this highly efficient generator amounts to about the same that we would have in the furnace of a 60 h.p. boiler. If you imagine a generator about 10 ft. high, and 11 ft. in diameter, almost solidly filled with magnetic material—an extremely compact structure, with certain spaces through it for ventilation—and then imagine this structure having heat delivered into it as fast as a 60 h.p. furnace could put it in, you will see that the problem of keeping that thing cool is quite a serious one. To keep it cool, we must have 30,000 ft. of air a minute pass through, and keep that air uniformly distributed; so that in no part will it become very hot; otherwise we will have some part of the machine burning itself up. Most of this work on the generators has been splendidly done, and a vast amount of inventive ability, skill and foresight have been put into it; but naturally, some mistakes have been made, and every little difficulty with a generator tends to hold back the turbine industry as much as if it were in the turbine. These troubles, however, have been overcome and corrected. All this has been very expensive, but the result is, that in five years, we have made the largest and by far the most efficient steam engine ever produced.

PRACTICAL DEMONSTRATIONS ARE CONVINCING

By E. L. Callahan

In this day and age when so many new devices and labor-saving conveniences are being brought before the people, in order to call attention to any particular one, it seems necessary to show the buying public just wherein that one excels, is particularly desirable, or well adapted to their use.

This is especially true of electric heating devices, for so many people are satisfied if results can be obtained, regardless of whether they are accomplished under favorable conditions or under unfavorable ones with arduous labor. Central stations and electrical concerns that have devices for sale have therefore found it very advantageous to their business to show their customers, by means of demonstrations, just how cooking by electricity can replace cooking by other means—how much labor, time and expense can often be saved by using electric irons in the laundry, and electric heating appliances in the industrial field.

Throughout the last year or two there has been scarcely a food show held that did not contain booths with extensive displays of electric cooking and heating devices, and practical demonstrations of electricity replacing gas for heating. It has become quite the custom for electric light companies to have brilliantly lighted and tastefully arranged and decorated booths at these shows, with several demonstrators in white aprons and caps busily engaged in cooking and baking, and offering dainty bits of cake and coffee to the many interested visitors.

At one food show which I visited about two weeks ago, I found that, with two or three exceptions, every booth that needed heat was utilizing the electric current, and the management felt secure for the reason that the fire hazard was reduced to a minimum.

Many cities have an electric show annually, and since it is a recognized fact that things in motion attract attention, most of these shows depend upon electric novelties and electric heating devices for special features of the exhibitions.

These public demonstrations are not confined to the large cities, but have been taken up and carried through very successfully during the last year by many small towns and cities throughout the United States. In towns of ten thousand or over there is scarcely an electric light company that does not have an exhibition and demonstration room. In many cities these are not elaborate, but they are the nucleus for a new business department that will surely bring rich returns to the aggressive companies in the near future.

At State electrical conventions the managers of many lighting companies, who have given little time to pushing the sale of current-consuming devices, have been convinced, after hearing reports from those who have been pioneers in pushing the new business methods, that their plants are not earning what they should. They have gone home with the resolve that they would take steps to secure an exhibition and demonstration room, with someone in charge who would visit customers in their homes and show them twentieth century methods.

It has been learned that carefully chosen solicitors will be received in the homes of the electric light company's customers, as the latter are glad to learn of the new conveniences that are being offered.

The domestic science departments of the various women's clubs are enthusiastic on the subject, and are doing much to help the lighting companies to advertise electric heating devices. An example of this was shown early last spring in a town of about 40,000 inhabitants, where the domestic science departments of these clubs secured a renowned lecturer who had taken up electric cooking, with the result that about 20 per cent. of the inhabitants attended during the two daily sessions held for ten days. The electric supply companies and lighting company did everything possible to aid them in making attractive exhibits. The main feature was a six room cottage, complete to the smallest

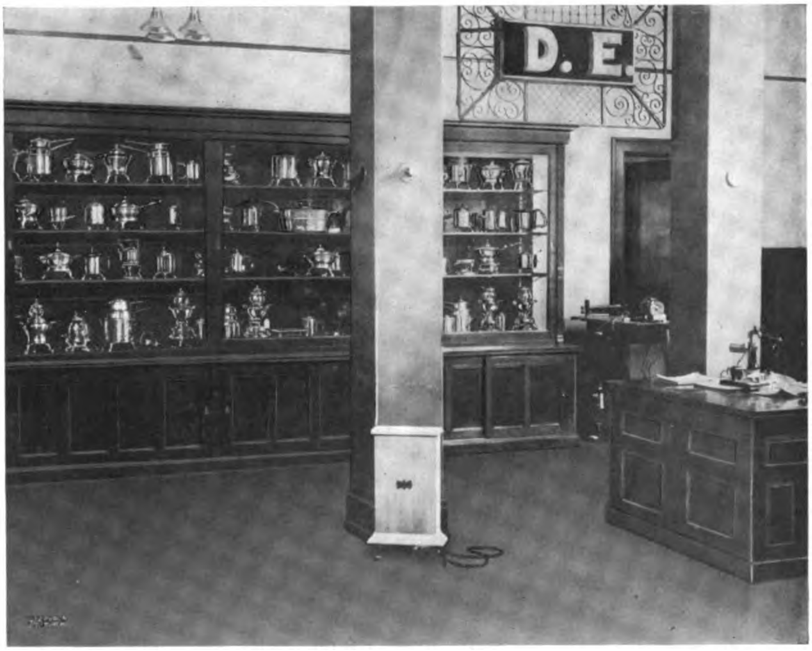


Fig. 1. Exhibition Room of the Detroit Edison Company

detail, which was located in the auditorium, and through which each visitor might walk and see what his or her home could be made like by the use of electric labor-saving conveniences, and proper lighting effects.

I am positive that the same success could be obtained in nearly every city in the United States, with excellent results and benefit to the electric company. At these lectures ladies secure valuable recipes for baking and cooking, having first seen them demonstrated, and those present are made to feel that they are being favored, rather than that they are conferring a favor on those in charge by attending.

A photograph of the cottage referred to above, which will give some idea of the completeness and care that was taken in building it, was shown in the December number of the Review. It was demonstrated in this cottage that the week's washing, drying, and ironing could be done in from two to three hours time, and with almost no labor. To accomplish the drying, a rough board box about 4 ft. by 12 ft. by 6 ft. high was built, and the clothes quickly dried by electric heaters and fans.

Recently, in a city in Kansas where there had been little activity on the part of the local lighting and gas companies, the public was treated to a surprise through a change of management. The gas and electric companies combined, and tried to outdo each other in presenting the more interesting program at a practical cooking demonstration and course of lectures on domestic science. In the electric cooking demonstration, a comparison was drawn between cooking in the old way and in the new way.

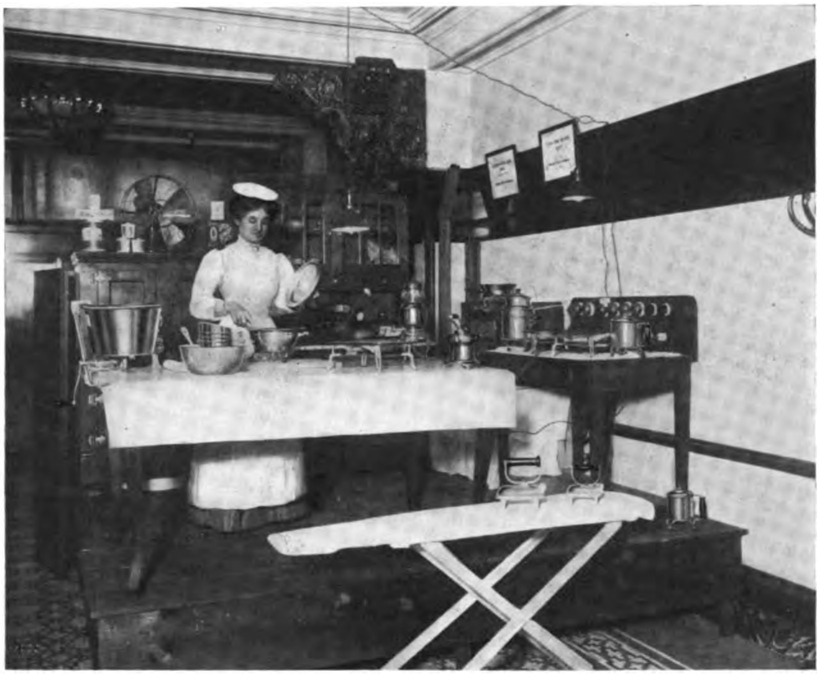


Fig. 2. Demonstration of Electrical Heating Devices in one of Chicago's Leading Department Stores

The above illustration will show that the expense of providing the necessary equipment to carry on such a practical demonstration is not great. The smallest central stations can well afford to teach their customers to use current-consuming conveniences, for the money thus spent will come back to them through increased bills for larger current consumption by the satisfied customers.

In Grand Rapids, Michigan, a course of lectures by the eminent lecturer referred to above, has just lately closed. The lectures were held in the Press Building, and the Electric Light & Power Company were silent partners, although they were back of the whole scheme, and were the builders of the model cottage through which each visitor had to pass to reach the lecture hall. As a result it was the most popular attraction in town for two weeks, and was the means of demonstrating the practicability of electric cooking to just the class of people that the lighting company wished to reach.

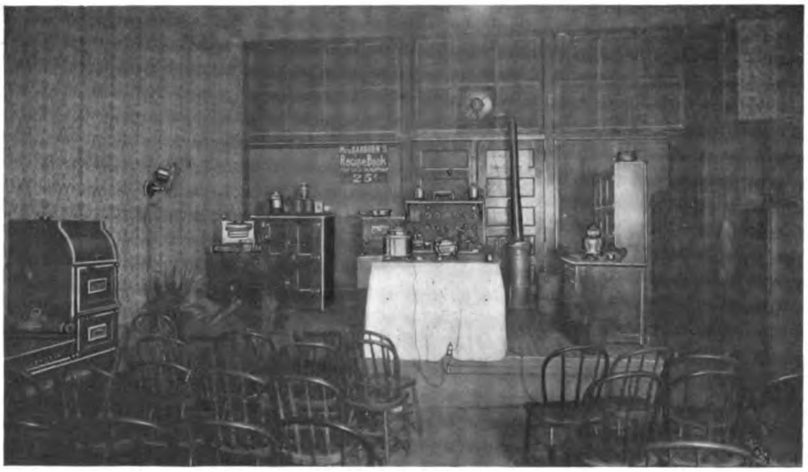


Fig. 3. Model Electric Kitchen of the Edison Light & Power Co., Wichita Gas & Electric Show, Wichita, Kan.

This kind of advertising is effective, and when followed up by personal solicitation, brings profitable business.

The Edison Illuminating Company of Detroit, Michigan, has one of the most completely equipped demonstration and show rooms to be found anywhere. Nearly every current-consuming device, from a two candle-power lamp to a refrigerating machine, is installed ready to operate before the customer. A model electric kitchen in tile does not leave the inquiring customer much room for imagination, for everything is as it should and could be at home.

Demonstrators can better impress customers when they can show and operate kitchen devices in a kitchen, luminous radiators in a bath room, bedroom or living room, and ironing in a laundry. Nearly one million electric irons would not be in use to-day if the central station had not given the customer an opportunity to demonstrate that they would do the work.

A leading department store in Chicago, realizing that, with the extensive advertising of the lighting company and the desire of the people to buy new things, it would be to their advantage to put themselves in a position to supply the demand, arranged with the lighting company to have an exhibition and course of lectures on cooking by electricity held in their dining room. The hundreds of shoppers who patronized their restaurant, and those who came for the lecture, went away quite enthusiastic over the interesting subject, and were especially delighted with the electrically cooked dainties.

The best scheme that I know of for giving the people a correct knowledge of the cost of operating these various devices is shown in Fig. 4. At one end of the demonstration room, and just outside of the fully equipped model kitchen, is a meter with a pasteboard dial having a circle described upon it, 12 inches in diameter and divided into twenty equal segments.

This is an old style five-wheel, or dial meter, the fifth wheel of which revolves once for each kilowatt registered. By extending the shaft three inches and attaching an aluminum hand, the current consumption in cents can be read by the observer at a glance; for instance, since the rate for cooking at Sault Ste. Marie is 2½ cents per kilowatt hour, if a broiler taking 1500 watts is used thirty minutes, the pointer will move 270 degrees around the dial, or show a cost of 1⅞ cents. The dial may be divided in any manner which best suits the rate in use.

It seems to me that the central station manager should make every effort to teach his customers the relative values of various apparatus as current consumers, compared with the best known standard. The custom of many stations is to use the 16 candle-power, 50 watt incandescent lamp as the standard. It is probable that this will not be a standard very much longer, but this standard is now more comprehensible to the layman than any other, and if he could see the relative current-consuming value of the 16 candle-power lamp and a two kilowatt air heater on a dial such as described above, the central station complaint department would not have so much work in adjusting customers' bills, and satisfying them that they had used all of the current with which they were charged.

If the customer is taught enough about electric measuring instruments to convince him that they measure the current accurately, and only when light, heat or motion is obtained, the central station man will relieve himself of the greater part of the complaints now received, and at the same time increase his revenue.

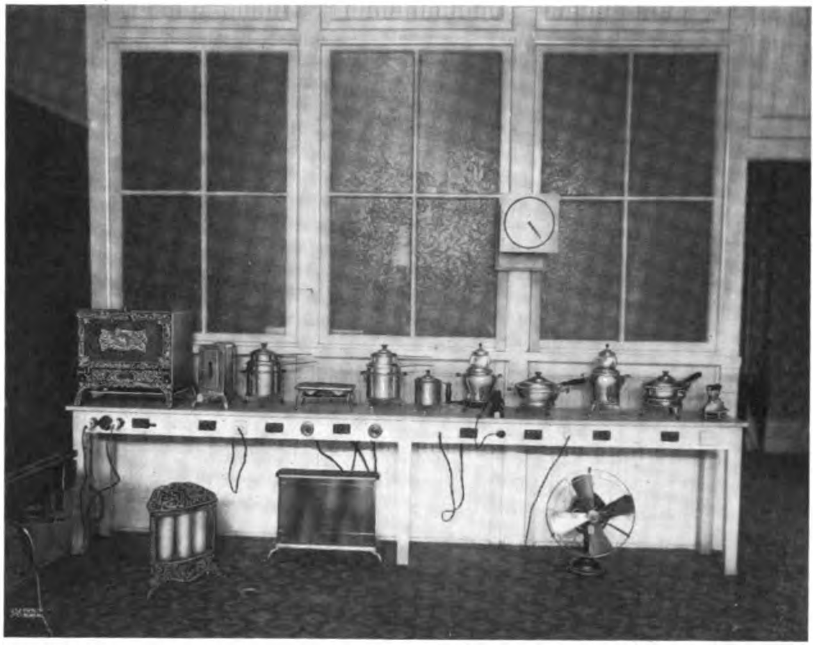


Fig. 4. Exhibition and Demonstration Room of the Edison Sault Electric Co., Sault Ste. Marie, Mich.

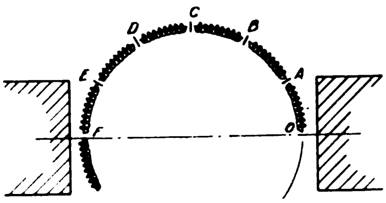
THE ROTARY CONVERTER

PART I

By E. J. BERG

In its general appearance the rotary converter resembles a direct current generator with two or more collector rings.

In its electrical characteristics it combines the features of the alternator with those of the direct current generator, and has many features of the stationary transformer.



Gram ring wound multiphase alternator

Fig. 1

In its action it is reversible, so that it can convert alternating current to direct current or *vice-versa*.

Depending upon the number of collector rings, a definite ratio exists between the direct current and alternating current voltage. As in the case of the transformer, this ratio is substantially constant at all loads and changes only by reason of the internal losses.

Voltage Ratio

With a sine wave of e.m.f. this ratio can readily be determined by referring to Fig. 1, which represents a Gramme ring wound, two-pole alternator, the armature of which is tapped at a number of points—O, A, B, C, D, E, and F.

Assume that the armature winding has t turns per pole, and that the effective alternating voltage generated per turn is E volts. In a single-phase alternator the voltage (represented in Fig. 1, as OF) would then be $\frac{2tE}{\pi}$, since the e.m.f's. generated in the individual turns are not in phase, their resultant being represented by the diameter instead of by one-half of the circumference.

In a three-phase converter the voltage is represented by the line OE, and is:

$$\frac{2}{3}\,t\,\frac{\frac{\sqrt{3}\,D}{2}}{\frac{\pi D}{3}} \times E = \frac{\sqrt{3}}{\pi}\,t\,E$$

In a four-phase converter (usually called two-phase converter) the voltage is represented by OC, and is:

$$\frac{2t}{4}\,\frac{\frac{\sqrt{2}\,D}{2}}{\frac{\pi D}{4}} \times E = \frac{\sqrt{2}}{\pi}\,t\,E$$

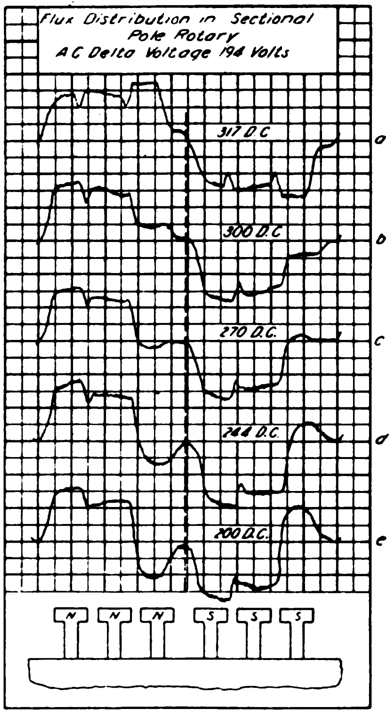


Fig. 2

In a six-phase converter the voltage is represented by OB, and is:

$$\frac{2t}{6}\,\frac{\frac{D}{2}}{\frac{\pi D}{6}} \times E = \frac{1}{\pi}\,t\,E$$

In a converter of m number of collector rings the voltage between adjacent rings is:

$$\frac{2tE}{m} \times \frac{m}{\pi} \cos\left(90 - \frac{180}{m}\right) = \frac{2t}{\pi} E \sin \frac{180}{m}$$

Since the direct current voltage corresponds to the maximum value of the single-phase alternating current voltage, its value is:

$$\frac{2tE\sqrt{2}}{\pi}$$

Assuming a fair flux distribution, such as is common in ordinary machines, the following relation exists, in general, between the alternating current voltage across adjacent collector rings of an m-phase rotary, and the direct current voltage:

$$\frac{\text{Alternating current voltage}}{\text{Direct current voltage}} = \frac{\frac{2tE}{\pi} \sin \frac{180}{m}}{2\frac{\sqrt{2}}{\pi} tE} = \frac{1}{\sqrt{2}} \sin \frac{180}{m}$$

This formula gives the following ratios for converters of the number of phases listed:

No. Phases	m	Ratio
1	2	.707
3	3	.613
4	4	.5
6	6	.353

With a greatly distorted flux distribution, such, for instance, as that shown in Fig. 2, the ratio changes very considerably. With a flux distribution as shown in a the ratio, three-phase to direct current voltage, was 0.615; as shown in b, 0.65; as shown in c, 0.72; as shown in d, 0.81; and as shown in e, 0.97. These diagrams are added to show how the ratio may vary. It is also of interest to note that in the first case, the ratio corresponds to that of a sine wave, although the flux distribution is far from such. We may therefore conclude that only very large distortions affect the voltage ratio.

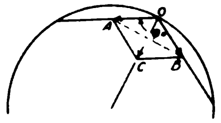
Current Ratio

In the following equations,

i denotes the effective alternating current in the windings;
i_a the effective alternating current in the lines;
i_c the direct current in the winding;
i_d the direct current in the lines;
e the alternating e.m.f. between lines;
e_d the direct current e.m.f. between lines.

The relation between the current in the winding and the current from a collector ring of a multiphase alternator is shown diagrammatically in Fig. 3.

Referring to Fig. 3, let $i = OA$, be the effective current in one side of the winding, and OB (also $= i$) the current in the other. Their resultant, which is the line current i_a, is then $2i \cos \frac{\phi}{2}$, where ϕ is the space angle between adjacent phases.



Relation between line current and current in a closed circuit winding of a multiphase alternator

Fig. 3

For an m-phase alternator, ϕ is $180 - \frac{360}{m}$, and therefore the line current i_a, corresponding to i amperes in the winding, is $i_a = 2i \cos\left(90 - \frac{180}{m}\right) = 2i \sin \frac{180}{m}$.

If e is the voltage between two adjacent collector rings, we get the total output = mie, which, when expressed as a product of line current and line voltage, may be written as:

$$\frac{mei_o}{2 \sin \frac{180}{m}}$$

but e, as shown above, may be expressed as follows:

$$e = \frac{e_d}{\sqrt{2}} \sin \frac{180}{m} \qquad (1)$$

where e_d is the direct current voltage.

Therefore, in a rotary converter assuming 100 per cent. efficiency, we may write the direct current output the same as we do the alternating current input. Denoting the direct current line current by i_d, and the direct current e.m.f. by e_d, we therefore get:

$$i_d e_d = \frac{m e i_a}{2 \sin \frac{180}{m}} = \frac{m}{2} \cdot i_a \cdot \frac{e_d}{\sqrt{2}} \frac{\sin \frac{180}{m}}{\sin \frac{180}{m}}$$

or the ratio of currents in the alternating and direct current lines.

$$\frac{i_a}{i_d} = \frac{2\sqrt{2}}{m}. \qquad (2)$$

This formula gives the following ratios for converters of the number of phases listed:

No. Phases	m	Ratio
1	2	$\sqrt{2}$
3	3	.943
4	4	.707
6	6	.472

The relation between the alternating current in a closed circuit winding and the direct current for the same output is directly obtained from the previous reasoning.

We have i, the current in the winding =

$$\frac{i_a}{2 \sin \frac{180}{m}}, \text{ and } i_a = \frac{2\sqrt{2}}{m} i_d. \qquad (3)$$

Since in a two-circuit winding the direct current in the winding is one-half of the line current, we therefore get the following relation between the effective values of the two currents, where i_a is the alternating, and i_c the direct current in the winding.

$$\frac{i}{i_c} = \frac{i_a}{2 \sin \frac{180}{m}} \div .5\, i_d$$

$$= \frac{1}{\sin \frac{180}{m}} \times \frac{i_a}{i_d} = \frac{2\sqrt{2}}{m \sin \frac{180}{m}} \qquad (4)$$

and the ratio of the maximum value of the alternating current to the direct current, in the winding, is

$$\frac{i_{max}}{i_c} = \frac{4}{m \sin \frac{180}{m}}. \qquad (5)$$

Thus, in a three-phase machine (m = 3)

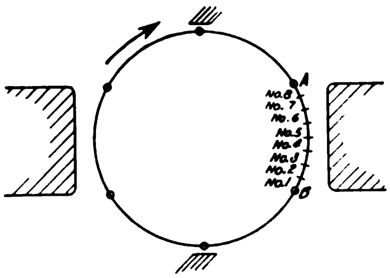
$$\frac{i}{i_c} = \frac{2\sqrt{2}}{3 \cos 30} = 1.09$$

and the ratio between the maximum value of the alternating current and the direct current is $1.09 \sqrt{2} = 1.54$.

In a four-phase machine $\frac{i_{max}}{i_c} = 1.414$, and in a six-phase converter, 1.333.

The armature heating, due to the I^2r losses, can best be studied by determining the instantaneous values of the resultant current in every coil during a revolution. Such analysis is given below for a six-phase converter with unity power factor.

Fig. 4 represents a two-polar, six-phase converter. The armature is assumed to consist of 48 coils, Gramme ring wound, and each phase has therefore 8 coils, displaced in space $\frac{360°}{48} = 7.5°$.



Two polar six-phase converter

Fig. 4

In the following analysis the condition existing in phase AB will be considered.

It is evident that when this phase is in the position shown in Fig. 4 its e.m.f. is a maximum; therefore, if the alternating current load is non-inductive; that is, if the rotary converter operates with such field excitation as to make the alternating current a minimum, the instantaneous value of the alternating current in this coil is also at its maximum at the same time. Let this maximum value of the alternating current be denoted by i_{max}, and the direct current in the winding by i_c. We then have, according to equation (5), the following relation between i_{max} and i_c.

$$\frac{i_{max}}{i_c} = \frac{4}{m \sin \frac{180}{m}} = 1.333. \qquad (6)$$

(*To be Continued*)

RAILWAY SIGNALS

PART IV*

BY F. B. COREY

Signal Mechanisms

Having studied the fundamental principles of automatic block signalling and some of the elementary circuits used for its operation, we now come to the consideration of the signal mechanisms which drive the semaphore arm or other device, by means of which the proper visual indication is given to the crew of the train. This is an apparatus which must be designed and built with the greatest possible care, as failure to perform its proper function may lead to most disastrous consequences.

One of the earliest types of mechanism was the clock work signal, a few of which are still in operation, although such signals are not manufactured at the present time. This signal consists of a circular banner supported on a vertical shaft, the latter being turned by means of a weight and train of gears. An escapement releases this train of gears and causes the banner to revolve in such a manner as to give the proper indication. The weight is wound up from time to time, as the conditions of operation require. The banner itself is largely made up of slats, like a blind; these slats being arranged to swing in the wind, so as to release the side strain that would otherwise occur. The mechanism is extremely simple, and the outward appearance of the apparatus is clearly shown in Figure 1. No new signals of this type have been erected since 1894.

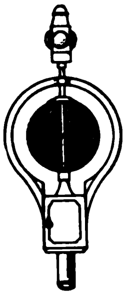


Fig. 1. Clock Work Signal

The simplest of all signal mechanisms is the purely electrical device used in disc signals, a typical form of which is shown in Figure 2. This mechanism consists merely of peculiarly designed magnets, so arranged as to turn the signal from stop to clear position, and hold it there. Mounted on the armature shaft is an arm which carries two discs, the larger one of which is made of cloth, to secure lightness, while the smaller disc is of very thin glass. The large disc is for the purpose of a day indication, and the smaller one serves as a colored roundel for giving the night signal. Such a signal, assembled in its case, is shown in Figure 3, which gives a back view of the case, with the door open; above the door is seen the bracket, which supports the signal lamp.

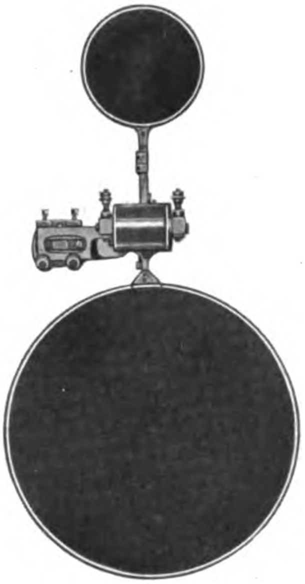


Fig. 2. Disc Signal, Operated by Electro-Magnets

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* Part III of this article appeared in the September issue

Passing now to the consideration of the mechanism for operating the modern semaphore arm, we come first to the electro-pneumatic signal, which has come into very extensive use. In this system compressed air is piped throughout the entire length of the road, and track circuit relays control electro-pneumatic valves for admitting air to the cylinder which contains the operating piston. It is arranged so that when the air is admitted to the cylinder, the signal is thrown to its clear position, and held there until the cylinder is exhausted by the release of the electro-pneumatic valve, or by failure of the air supply. A sectional view of such a cylinder and valve is shown in Figure 4, and a complete signal of this type is shown in Figure 5.

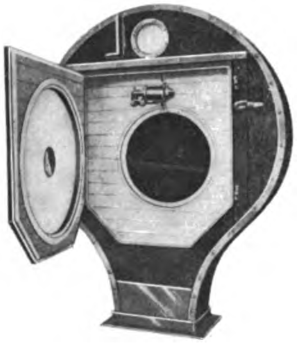

Fig. 3. Disc Signal Assembled in Case

An interesting modification of the electro-pneumatic principle is the electro-gas signal, operated by gas pressure. In this signal the operating medium is carbonic acid gas (CO_2), which is stored in steel cylinders or tanks, where it is liquified by pressure. The storage tanks, which are similar to those used in the ordinary soda fountain, are placed in a battery chute of the usual type, close to the base of the signal. To absorb the moisture which is always present and thus prevent freezing, a small amount of alcohol is introduced into each cylinder, but this precaution does not entirely eliminate trouble from that source. A reducing valve is provided to regulate the pressure of the gas that is admitted to the operating cylinder. A small auxiliary reservoir, containing gas at the reduced pressure, is located in the mechanism case, and this serves for the direct supply to the operating cylinder, which is movable upon a stationary piston as shown in the section of Figure 6. An elevation of a two-arm signal of this type is shown in Figure 7. Large numbers of these signals have been installed and are in successful operation; at the present time, however, they are not being installed in as large numbers as formerly, as it is quite generally admitted that they are less satisfactory than the electric motor signal, which is now the most popular type.

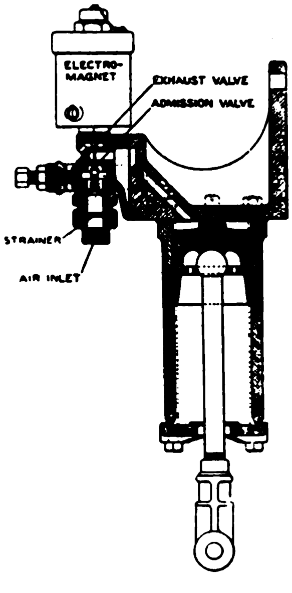

Fig. 4. Section of Cylinder and Valve, Electro-pneumatic Signal

The earliest form of electric motor signal to come into extensive use was the "Style B" signal, which is manufactured by the Union Switch & Signal Company, and is being built in large quantities at the present time, in practically its original form. The latest design of this signal is shown in Figure 8, which gives a good idea of its principal parts. The electric motor, through double reduction gears, drives a shaft which carries a sprocket wheel, while the upper part of the frame of the signal carries another sprocket, the two wheels being connected by means of an ordinary sprocket chain. To this chain is attached a roller, shown in the illustration near the upper end of its travel. The signal arm is operated by a vertical rod which is provided with a screw-jaw fastened to a casting called the "slot-arm;" this slot-arm carries a magnet, known as the slot-magnet, and the armature of this magnet is carried on a lever, the end of which engages a long hook attached to a bell-crank. This bell-crank engages another lever, which in turn is fastened to still another crank. This latter crank is so shaped as to engage the roller that is carried by the sprocket chain. When the signal circuit is closed the motor is started and the slot-magnet energized; with the slot-arm then in its lower position, the roller engages with the catch, raising the slot-arm, which in turn raises the rod, operating the signal blade. When the signal reaches its clear position the roller disengages the slot-arm and the latter drops back slightly, and is held by a lug on the frame of the mechanism. The motor circuit is then broken by the current controller, which is seen at the lower right-hand corner of the illustration, and the signal is held in its clear position as long as the slot-

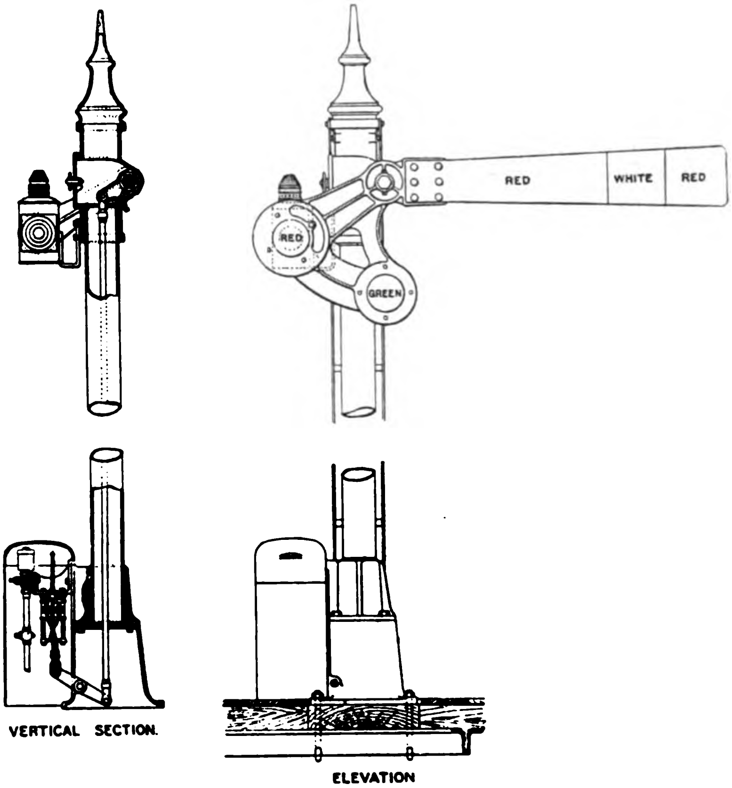

Fig. 5. **Electro-pneumatic Semaphore**

magnet is energized by the relays. The motor is stopped by means of a magnetically operated friction brake. When the signal is released the shock of its fall is absorbed by the dashpot, shown at the upper right-hand corner of Figure 8. The mechanism illustrated is for a two-arm signal, and therefore carries two sets of sprocket wheels, two sprocket chains, slot-arms, etc. When this signal is used for a one-arm three-position signal the same mechanism is used, with the addition of two racks, each carried by a slot-arm, with a floating pinion between the two racks which is carried by the signal-operating rod. This signal is described in detail on account of the fact that there are now nearly 25000 of them in service.

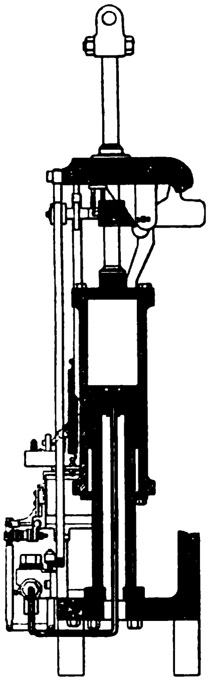

Fig. 6. Section of Operating Cylinder, Electro-gas Signal

It will be noted that all of the signal mechanisms above described are located at the bottom of the signal mast, and are connected to the signal arm by a vertical rod extending through the interior of the pipe mast. This arrangement involves the conversion of the rotary motion of the motor and gears to a reciprocating motion, and then again to a rotary motion at the semaphore bearing. In order to make a more direct application of the power, and thus avoid the difficulties and losses incident to such an indirect connection, a class of signals has been recently developed which are known as top-mast signals. In this class of signals the motor and other mechanism are located at the top of the signal mast, and in this way direct connection with the semaphore arm is secured.

All of the signals manufactured by the General Electric Company are of the top-mast type. With this arrangement it is possible to insulate the mechanism and its case from the signal mast and ladder, and this avoids, to a large extent, the possibility of trouble due to defective insulation of the

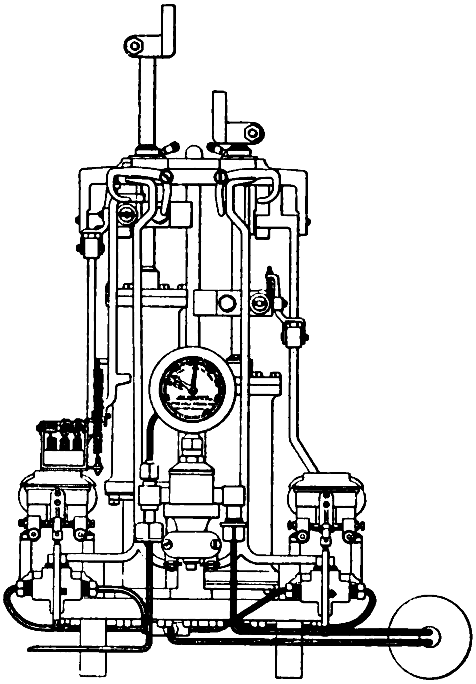

Fig. 7. Elevation of Two-arm Electro-gas Signal

mechanism parts, or to careless wiring when the signal is installed. The top-mast construction permits of the installation of a signal on any kind of pole with the least possible labor. The mechanism is located above the surface moisture and out of the reach of floods, and in locations where heavy snows occur, it facilitates the inspection and care of signals without the necessity of removing the snow from around the base of the pole. By doing away with the connection between the bottom and top of the pole considerable power is saved, and since such signals are usually operated from primary batteries any saving in power is of importance. The only objection that has been raised against the top-mast arrangement is that the maintainer is obliged to go to the top of the mast to inspect and care for the signals. In practice, however, those who have had experience with top-mast signals of the proper design are heartily in favor of this construction.

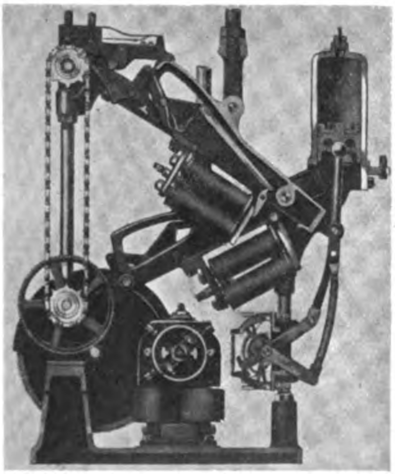

Fig. 8. Early Type of Electric Motor-Operated Signals

Figure 9 shows the General Electric Company's M-110 signal mechanism, complete in its case. This signal is of the three-position type. The motor is geared in such a way as to revolve the clutch wheel, which turns freely about the main shaft, while this shaft extends through the case for the reception of the signal arm. Mounted upon this shaft, and rigidly attached to it, is the sector casting which supports the clutch magnet, and which also provides, by means of the locking magnet seen at the top of the mechanism in Figure 9, a method of locking the signal in its caution and clear positions. The return of the signal to either caution or stop position is accomplished by gravity, without the movement of any of the gearing, thus

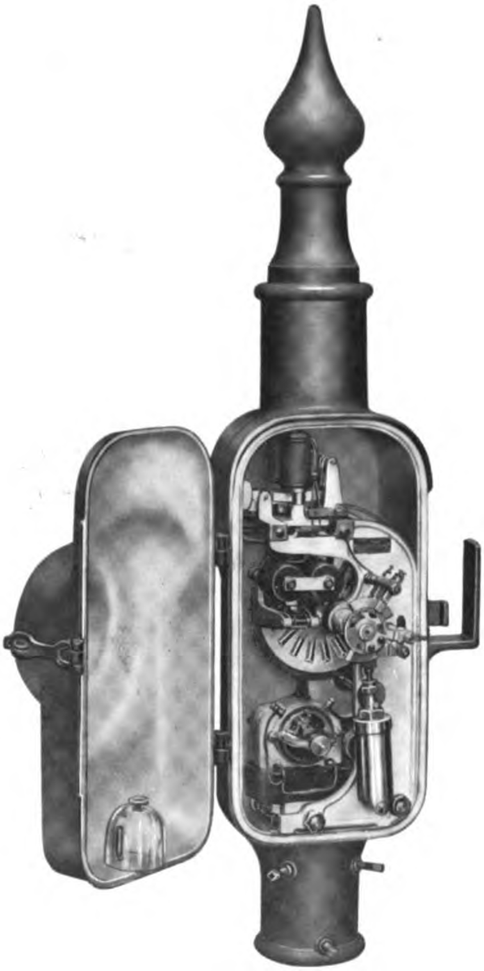

Fig. 9. General Electric Motor-Operated Three-Position Signal, Type M-110

avoiding all unnecessary friction. This gravity movement is retarded by means of a simple dashpot, shown at the lower right-hand side of the mechanism. For a complete description of this signal, reference is made to General Electric Bulletin No. 4484.

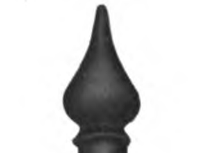

Fig. 10. General Electric Motor-Operated Two-Position Signal, Type M-113

The General Electric Company has recently placed on the market a two-position, top-mast motor signal, which embodies a number of novel features, both electrical and mechanical, and is known as the M-113. The frame of the mechanism, which supports the main shaft bearing and the bearings for the reduction gears, is made so as to form a weatherproof case; and, with the door attached to it, this forms a complete protection for the working parts. This construction greatly reduces the number of parts required, and insures a more perfect alignment of the bearings than could be otherwise obtained. This mechanism is shown in Figure 10. The motor, by means of intermediate gears, drives the main gear, and to this latter gear are attached five steel driving pins which engage a pawl carried by the slot-arm. This slot-arm is secured to the main shaft, and serves to drive the signal to its clear position. The return of the signal to the stop position is effected by gravity, and this movement is cushioned by a buffer at the back of the driving gear. The stopping of the motor at the clear position is effected by converting the motor into a generator, and for this purpose a shunt field winding is provided, in addition to the series field. The electrical connections are shown in Figure 11. For a complete description of this signal, reference is made to General Electric Bulletin No. 4536.

The last two signals described above show the highest development attained, respectively, in these types of electric motor signals. It is believed that future development will be along the line of the top-mast construction, as it is universally recognized that reliability of operation is the supreme object of the signal engineer and of the signal manufacturer.

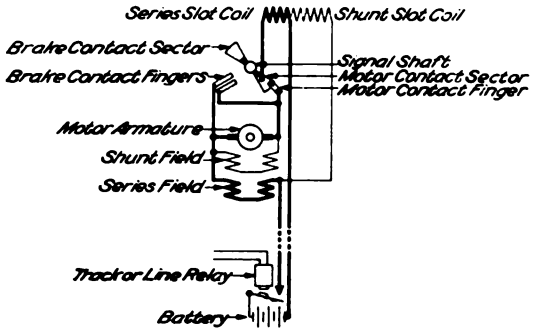

Fig. 11. Diagram of Connections, Type M-113 Signal

(THE END.)

NOTES ON THE DETERMINATION OF RAILWAY POWER STATION CAPACITIES

PART I

By E. E. Kimball

The object of this article is to outline briefly the general procedure followed by engineers in preparing estimates on the power required for the operation of proposed trolley roads, and also to present some interesting data in connection with train resistance and energy consumption which will be of great assistance to those who are frequently called upon to make technical recommendations on substation and power station apparatus, distributing system, size of motors, etc.

Requests for engineering recommendations are usually accompanied by a profile of the proposed road, showing grades, curves, location of stations, etc., and a description of the nature and volume of traffic the railway company expects to handle. Prior to the determination of the power station load, certain conditions more or less dependent upon each other must be definitely determined, and in order that these conditions may be properly emphasized and a logical procedure adopted, the following outline showing the steps in the calculations has been included:

1. Determination of schedule speed as governed by the frequency of stops, alignment, and profile of road.
2. Determination of car weight from seating capacity, motor weight, and maximum speed.
3. Determination of energy consumption of trains.
4. Determination of distribution losses.
5. Determination of headway, number of cars, and construction of train sheets.
6. Determination of station load diagram from train sheets, average kilowatt per car and distribution losses.

The determination of schedule speeds from the motor characteristics by the method of plotting *speed-time-energy* curves requires a knowledge of train resistance values, as well as the fundamental laws of force and motion. For this reason it seems advisable to show the development of certain fundamental constants which enter into the calculations of a great many railway problems.

Train resistance is that force which is directly opposed to the movement of a car or train, and includes rail and flange friction, rolling and bearing friction, wind resistance, etc. Within the past few years a great many tests have been taken, both in this country and abroad, to determine values of train resistance at various speeds with several different types of equipment, and under more or less favorable conditions of track, roadbed, etc., and after a very careful investigation of the conditions which existed in the actual tests, it was found that a single empirical formula could be derived which represents the test values very closely. This formula is as follows:

$$F = \frac{50}{\sqrt{T}} + .03V + \frac{.002V^2}{T} A \left(1 + \frac{N-1}{10}\right)$$

Where F = train resistance in lb. per ton.
T = total weight in tons.
V = speed in miles per hour.
A = end cross section in square feet.
N = number of cars in train.

$\frac{50}{\sqrt{T}}$ has been limited to a minimum value of 3.5.

It is unnecessary to enter into the method employed for deriving the above formula, since one is seldom concerned with the bearing, rail and flange frictions, etc., as separate items, but it is interesting to note that the last term represents the effective wind pressure upon the head-end and sides of the cars. Various tests have been taken to determine the variation of this pressure upon the front end of succeeding cars in a train and it was found to be about 10 per cent. of the total

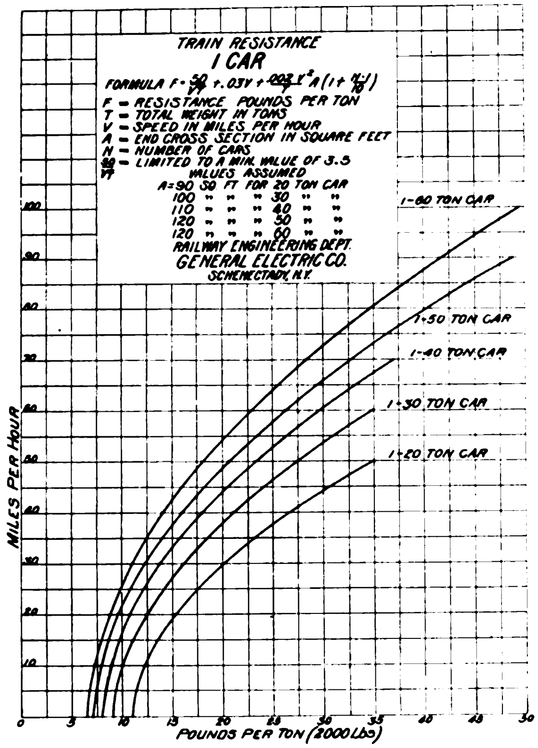

Fig. 1

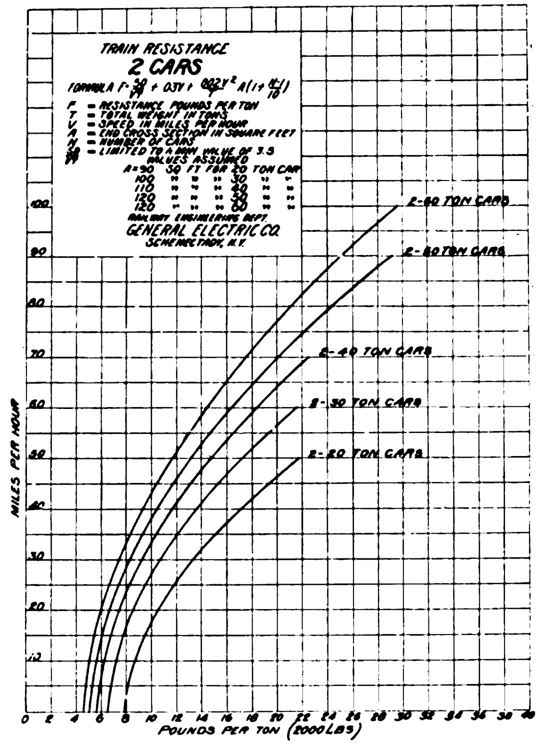

Fig. 2

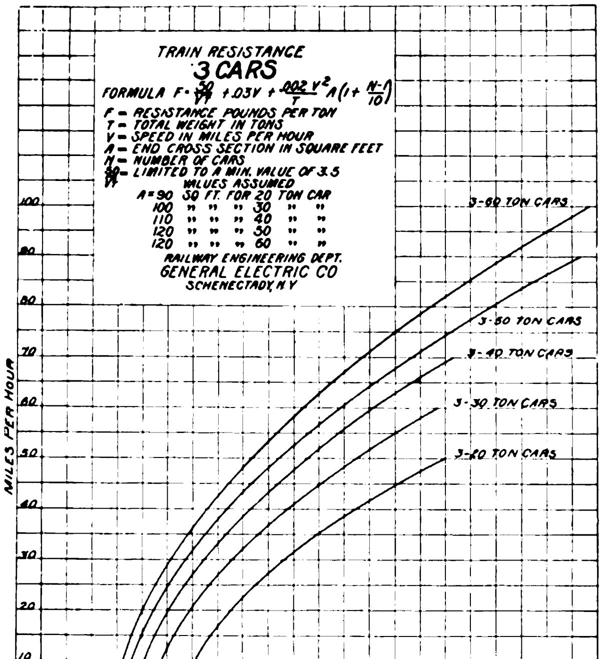

Fig. 3

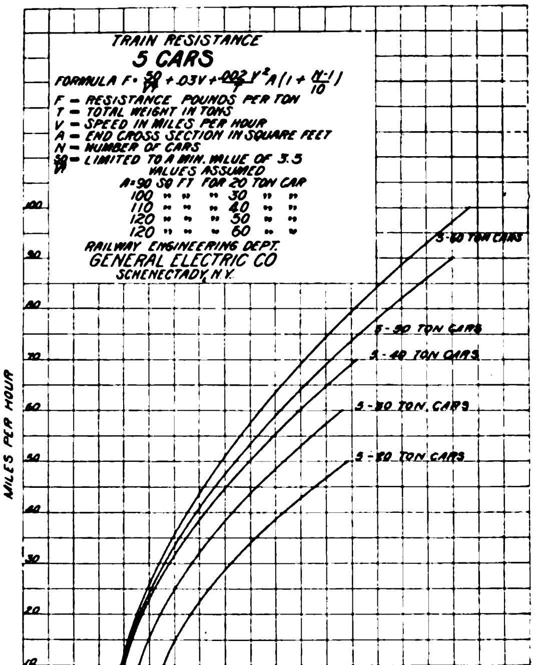

Fig. 4

pressure on the first car. It should be noted that the formula is perfectly rational in this respect.

In order to present the data on train resistance in the readiest manner for reference, the above formula has been worked up in curve form for various weights of car, area of end cross section, number of cars in train, etc. These curves form the basis of the calculations and tables which follow.

It is customary to speak of a grade as so many per cent., meaning thereby the ratio of the distance raised to the distance covered; hence, the component of gravity along the grade, and opposed to the movement of a train *up* is equal to 20 lb. per ton (2000 lb.) for every one per cent. grade.

Curves are rated in two ways; namely, by degrees and by radius. The first method is adhered to by steam railroad engineers, since here the curves are seldom greater than 10 or 15 degrees, which permits surveyors to easily line in a curve with a transit. A one degree curve is one so constructed that a 100 ft. chord will subtend, at the center of the circle, an angle of one degree. Hence the radius of a one degree curve is $\frac{360 \times 100}{2\pi}$ = 5730 ft., and the radius of any other curve

$$n^\circ = \frac{5730}{n} = \text{feet radius approximately.}$$

Curves have, however, little bearing upon energy consumption of cars on account of their limited length, but it has been found that the *rail and flange friction while rounding a curve increases approximately at the rate of ½ lb. per degree of curvature.*

Frequently the distance between stops is so great that the equipment may be maintained running at constant speed over the greater portion of the run. Thus it is essential to know the power taken by a train when running at constant speed, in order to determine the size of trolley and feeder, and the drop between substations, as well as the load on the main station. During constant speed running the power supplied to a train is just sufficient to overcome the train resistance, and the losses in the motors and control, etc.

Hence,

Horse-power output at rim of the wheels

$$= \frac{\text{T x F x feet}}{\text{33000 x minutes}}$$

$$= \frac{\text{T x F x miles x 5280}}{\text{33000 x hours 60}}$$

$$= \frac{\text{T x F x V}}{375}$$

When reduced to kilowatts the formula becomes

Kilowatt output at rim of wheels

$$= \frac{\text{T x F x V x 746}}{\text{375 x 1000}}$$

$$= \frac{\text{2 x T x F x V}}{1000} \text{ approximately}$$

and kilowatt input to train $= \frac{\text{2 x T x F x V}}{\text{1000 x eff}}$.

Where T = total weight of train.

F = train resistance, including that due to grades and curves, in lb. per ton.

V = speed in miles per hour.

eff. = efficiency of the motors at the speed V.

The table on page 80 has been inserted to show the kilowatt input required by trains of different compositions running at various speeds, assuming standard cross sections for cars of various types.

The formula for energy consumption derived from the expression for kilowatt input is:

Watt hours per ton mile =

$$\frac{\text{2 x T x F x V}}{\text{Eff.}} \text{ x } \frac{1}{\text{T x V}} = \frac{\text{2 x F}}{\text{eff.}}$$

The actual energy consumption in any service will always be greater than the value thus derived, but will approach this value as the distance between stops increases.

Speed-Time-Energy Curves:

It is quite evident that the problem usually met on the majority of interurban and city trolley lines requires further investigation, since the distances between stops are usually so short that the equipment has barely time enough to reach maximum speed before power is shut off and the brakes applied. This requires the construction of speed-time-energy curves, which consists in plotting instantaneous values of speed, current, volts and distances, corresponding to various sec-

TABLE I

KILOWATT INPUT AT TRAIN, CONSTANT SPEED RUNNING ON TANGENT LEVEL TRACK

MOTOR CAR SERVICE

SINGLE-CAR TRAIN

Speed in Miles Per Hour	10	20	30	40	50	60	70	80	90	100
20 Ton Car	6.5	16.2	32.0	56.7	93.5	....	....	....	....	....
30 " "	8.0	19.5	38.4	67.3	109.0	167.0	....	....	....	....
40 " "	9.4	23.1	44.1	76.2	124.0	188.0	276.0	....	....	....
50 " "	10.4	25.6	49.2	84.8	137.0	210.0	305.0	430.0	584.0	....
60 " "	11.5	27.9	52.8	90.2	144.0	218.0	316.0	442.0	599.0	792.0

TWO-CAR TRAINS

2-20 Ton Cars	9.3	22.4	42.5	72.5	116.0	....	....	....	....	....
2-30 " "	11.5	27.4	51.4	87.0	137.0	206.0	....	....	....	....
2-40 " "	13.2	31.6	59.0	99.3	156.0	234.0	336.0	....	....	....
2-50 " "	14.8	35.5	66.3	111.0	175.0	261.0	374.0	520.0	699.0	....
2-60 " "	16.3	38.8	71.7	119.0	185.0	274.0	390.0	540.0	720.0	945.0

THREE-CAR TRAINS

3-20 Ton Cars	11.4	27.2	50.9	84.1	136.0	....	....	....	....	....
3-30 " "	14.0	33.3	61.8	103.0	162.0	240.0	....	....	....	....
3-40 " "	16.3	38.7	71.5	119.0	185.0	271.0	391.0	....	....	....
3-50 " "	18.4	43.7	80.6	134.0	206.0	308.0	437.0	602.0	805.0	....
3-60 " "	20.1	48.0	87.4	144.0	222.0	326.0	460.0	635.0	925.0	1092.0

FIVE-CAR TRAINS

5-20 Ton Cars	14.8	35.3	65.4	109.0	171.0	....	....	....	....	....
5-30 " "	18.3	43.5	80.0	133.0	205.0	303.0	....	....	....	....
5-40 " "	21.3	50.8	93.2	154.0	237.0	348.0	493.0	....	....	....
5-50 " "	26.2	61.9	112.0	183.0	279.0	406.0	568.0	773.0	1026.0	....
5-60 " "	31.3	72.8	130.0	208.0	312.0	448.0	622.0	835.0	1100.0	1415.0

Constants Assumed

Efficiency at full speed taken at 75 per cent. and based upon the use of d.c. geared motors.

Train resistance obtained from formula $F=\frac{50}{\sqrt{T}}+.03V+\frac{.002AV^2}{T}\left(1+\frac{N-1}{10}\right)$

Cross sectional area of cars as follows:—

20 Ton Car, Cross Section	90 square feet
30 " " " "	100 " "
40 " " " "	110 " "
50 " " " "	120 " "
60 " " " "	120 " "

onds of time after car starts from rest. See Fig. 6. It will be noticed that the speed curves can be divided into five parts, namely:

Acceleration, A to B;
Motor curve acceleration, B to C;
Constant speed running, C to D;
Coasting, C to E;
Braking, E to F.

Acceleration consists in bringing a car up to speed by notching up the controller, during which time the voltage impressed upon the motor terminals is always less than the line potential, or full voltage of the motors. During this period the rate of acceleration can be held approximately constant by cutting out resistance as the car speeds up. As soon as full voltage is impressed upon the motor, the rate of acceleration gradually decreases until the input to the motors is just sufficient to keep the car running at constant speed. This portion of the speed curve between constant acceleration and constant speed running is therefore designated as motor curve acceleration, since its shape depends upon the characteristics of the equipment employed.

In order that a motorman may make accurate stops, it is frequently necessary that the power be shut off some distance before the brakes are applied. During this period the momentum of the car is sufficient to keep it running at a constantly decreasing speed, which is designated as *coasting*.

Braking consists in applying a force opposed to the revolutions of the wheels, in order to produce retardation. The phenomenon is therefore the opposite of acceleration, and may be treated the same way.

Strictly speaking, *acceleration* or *retardation* is the rate of change of velocity, and is expressed in feet per second per second. In railway problems, however, acceleration is usually defined in miles per hour per second. Thus, an acceleration of one mile per hour per second means an increase in speed of one mile per hour during each second, so that in *n* seconds after starting from rest a train will be running at *n* miles per hour. The force required to produce a given acceleration is obtained from the formula:

Force = mass x acceleration,

where force is expressed in pounds, and acceleration in feet per second, per second;

$$\text{mass} = \frac{\text{weight}}{32.2}.$$

Hence,

$$\text{Pounds} = \frac{\text{weight in pounds}}{32.2} \times \frac{\text{feet}}{\text{seconds} \times \text{seconds}}$$

$$= \frac{2000 \times \text{tons}}{32.2} \times \frac{5280 \times \text{miles}}{3600 \times \text{hours}} \times \frac{1}{\text{seconds}}$$

$$= 91.1 \times \text{tons} \times \text{miles per hour per second}$$

Hence, an acceleration of one mile per hour per second requires a force of 91.1 lbs. per ton.

In accelerating a train it is also necessary to accelerate the revolving parts, which is equivalent to about 7 per cent. more weight. The following table gives the accelerating rates usually obtained in practical operation:

Accelerating Rates

	Miles per hr. per sec.
Steam locomotive, freight service,	0.1 to 0.2
Steam locomotive, pass. service,	0.2 to 0.5
Elec. locomotive, pass. service,	0.3 to 0.6

Motor Cars

	Miles per hr. per sec.
Electric motor cars, interurban service,	0.8 to 1.3
Electric motor cars, city service,	1.5
Electric motor cars, rapid transit service,	1.5 to 2
Highest practical rate,	2 to 2.5

For a comparison of acceleration tests with steam locomotives and electric motor cars, see B. J. Arnold and W. B. Potter's paper read before the American Institute of Electrical Engineers, June 19, 1902, Vol. 19.

For the same brake-shoe pressure the braking rate is greater for low speeds than for high speeds, on account of the decrease in the coefficient of brake-shoe friction. It is usual, however, to assume a braking effort of about 120 lbs. per ton gross for ordinary service applications on interurban lines. On steam roads the rate of braking of freight trains is considerably less on account of the time required to apply the brakes on all cars, and the necessity of reducing shocks to equipment and lading (caused by running in and out of the slack) to a minimum. A fair value to assume for the braking rate of freight trains is about 0.5 miles per hr. per second.

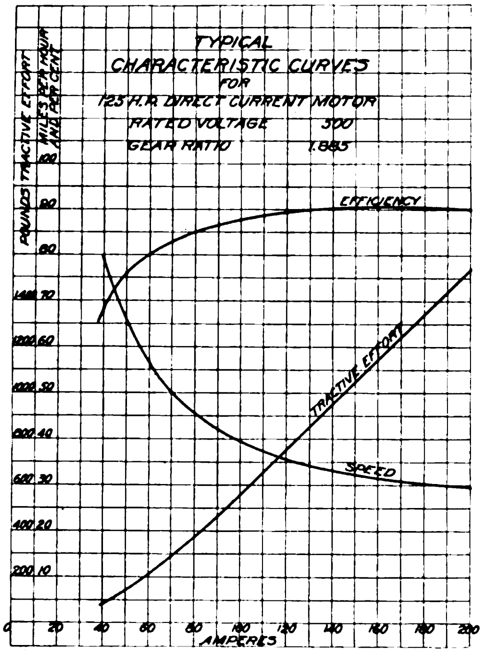

Fig. 5

The distance covered in a given time is equal to the product of the speed and time, where the distance is given in feet, speed in feet per second, and time in seconds.

Hence,

$$\text{Feet} = \frac{\text{feet}}{\text{seconds}} \text{ x seconds} = \frac{5280 \text{ x miles}}{3600 \text{ x hours}} \text{ x seconds} = 1.467 \text{ x miles per hr. x seconds.}$$

Hence a speed of one mile per hour is equivalent to 1.467 feet per second.

During acceleration and braking the speed is uniformly changing; hence it is necessary to take the average speed, thus:

$$\text{feet} = \tfrac{1}{2} \text{ x speed x time} = \tfrac{1}{2} \text{ x acceleration x seconds}^2.$$

The above formulae are all that are necessary for the construction of speed-time-energy curves. The actual calculations, however, are best arranged in a table as shown on page 83 where a few points of Fig. 6 have been calculated to illustrate the procedure. The data assumed in these calculations is as follows:

Weight of car	40	Tons
Effective weight of car	42.8	Tons
Number of motors	4	
Rated horse-power of motors	125	
Characteristic curves of motor	Fig. 5	

Accelerating current per motor $\frac{125 \text{ x } 746}{89 \text{ x } 500} =$ 210 amperes.

Accelerating constant per motor $\frac{42.8}{4} \text{ x } 91.1 =$ 975.

For other methods of calculating speed-time curves, see C. O. Mailloux's paper read before the American Institute of Electrical Engineers, June 19, 1902, volume 19.

The schedule speed is obtained by dividing the distance covered in miles by the time of cycle plus stops in seconds, and multiplying by 3600. It is also customary to allow about 10 per cent. leeway in the running time to allow for reductions in speed while rounding curves, and to enable the equipment to make up time in case of forced delays. If the lay-overs at the end of the line are long there is little need of allowing any leeway in the running time, as delays may be taken out of the lay-overs.

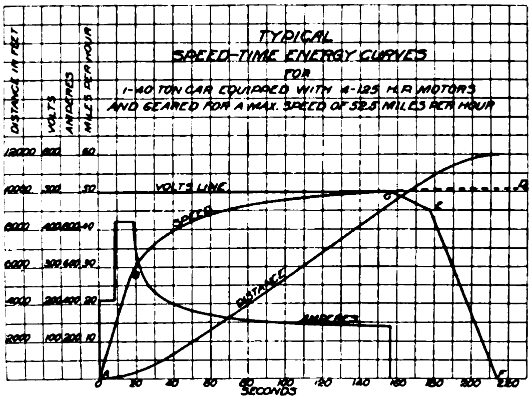

Fig. 6

TYPICAL SPEED-TIME-ENERGY CURVE CALCULATIONS

1	2	3	4	5	6	7	8	9	10
From	Motor	Curves		(3)-(4)	$\frac{(5)}{975}$	$\frac{V_n - V_{n-1}}{(6)}$	$\Sigma(7)$	$\frac{V_n + V_{n-1}}{2} \times (7) \times 1.467$	
Speed V	Amperes Per Motor	Tract. Effort Per Motor	Train Friction Per Motor	Net Tract. Effort Per Motor	Accel. M.P. H.P.S.	Time in Seconds	Total Time From Start	Distance in Feet	Total Dist. From Start
1. 29.0	210	1650	130	1520	1.560	18.6	....	295	....
2. 30.0	185	1400	140	1260	1.290	.78	19.4	34	329
3. 35.0	123	800	160	640	.655	7.6	27.0	362	691
40.	98	540	180	360	.369	13.5	40.5	743	1434
45.0	81	385	205	180	.185	27.0	67.5	1685	3119
n-1 50.	70	290	235	55	.056	89.2	156.7	6200	9319
n. 52.5	65	250	250	0	....	....	....	....	....
Coasting From 50 M.P.H. to 45 M.P.H.									
45	....	....	235	-235	-.241	20.7	177.4	1440	10759
Braking 120 Pounds Per Ton Gross									
....	....	....	....	-1200	-1.23	36.6	214.0	1210	11969

For the figures enclosed in parentheses, substitute the constants from the corresponding columns.

(To be continued)

THREE-PHASE—SINGLE-PHASE TRANSFORMATION

By W. S. Moody

The fact that it is impossible to take single-phase power from a quarter-phase or three-phase system by means of static transformers, and distribute this power over the several phases, was well demonstrated long ago. The desirability of accomplishing this result is so great however, that many persons who should know better frequently forget and ask if it is not possible. The following note on the subject is given to show the impossibility of securing this result.

The subject is perhaps most simply treated in Dr. Steinmetz's article, published in the Transactions of the American Institute of Electrical Engineers, for 1892. In this article Dr. Steinmetz shows that the difference between single-phase and polyphase systems is; that in the former the power delivered changes from maximum to zero and back to maximum every half cycle; whereas in the latter the rate of power delivered is constant. Therefore, any system, if it be capable of trans-

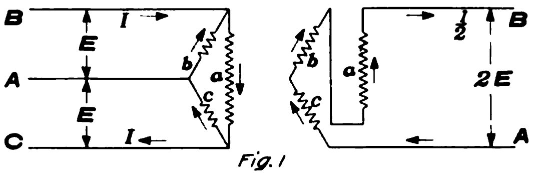

Fig. 1

forming from balanced polyphase current to single-phase current, must be capable of storing up energy during the interval of time when the power delivered to the single-phase side is less than the power received from the three-phase side.

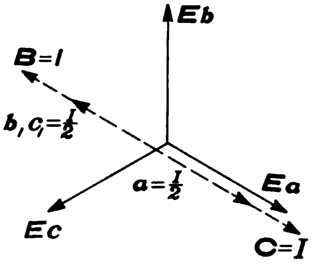

Fig. 2

The static transformer is evidently incapable of storing any energy, and therefore cannot possibly act as a means of transforming balanced three-phase current into single-phase current, or *vice versa*. To those who like to consider such problems in a mathematical way, the following demonstration, which was worked out by Mr. L. F. Blume at my request, will be interesting. In this he takes one of the suggestions sometimes offered for accomplishing the result; namely, the employment of three transformers, two connected in open delta and the third in reverse delta arrangement to the other two; and shows with diagrams that the whole combination is simply equivalent to a single transformer across one or two phases of the supply.

Fig. 1 shows a normal delta, and an open delta with the third phase reversed. Fig. 2 gives the voltages and current relation of the primary side, and Fig. 3 the same for the secondary side.

If E is the primary three-phase voltage, then, with a ratio of unity between coils, the voltage AB of the secondary will be 2E, as shown. Suppose a non-inductive receiving circuit takes a current x from the secondary; then, to balance the fluxes, the primary coils must each supply currents x in phase with the current in the respective secondary coils. Therefore, having only a single-phase current x in the secondary, the currents in the primary coils are equal in amount, and in the same direction as that in the secondary—except in the reversed coil, which merely turns the current vector through 180 degrees.

The current in main A will be the vector sum of the currents in coils b and c, or zero. In main B, the current will be the vector sum of the currents in coils b and a, or 2x; and similarly the current in the main C will also be 2x.

If I is the maximum effective current permissible in any primary main, then the value of x is $\frac{I}{2}$. Therefore the maximum effective secondary current is $\frac{I}{2}$, and the amount of power delivered to a non-inductive load is $2E \times \frac{I}{2}$, or EI.

Results just as good are obtained by simply using one single-phase transformer connected across two of the mains. In this case the maximum power delivered to a non-inductive load would be EI, the primary current being I in two of the legs, and zero in the third leg. It is therefore seen that nothing is gained by the suggested method, while much is lost in simplicity and efficiency.

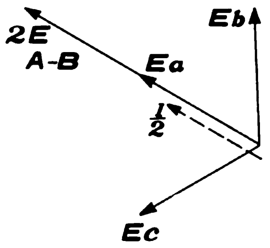

Fig. 3

Other combinations have been investigated in the same manner, and in no case has it been possible to obtain a better result than that secured by using one transformer across two legs.

CELLULOSE ACETATE COVERED WIRE

By R. Fleming

Insulated copper wire is such a ruling factor in the design and manufacture of electrical apparatus, that any process which reduces either the cost of the insulated wire, or the amount required, is of great commercial importance.

Silk and cotton are about the only materials which have been used in the past for insulating purposes. The former is relatively expensive, while the latter, though cheap, occupies an unfortunately large proportion of the winding space, especially when the wire itself is small.

Various chemical solutions have been applied to wires in the attempt to secure a thin, though permanent insulation, which would be more economical to use than silk or cotton. Cellulose acetate, enamel, collodion, casein, albumen, glue, rubber, silk solutions, etc., were tried with more or less favorable results, but for commercial purposes cellulose acetate and enamel have proven to be the substances best adapted to the insulation of copper wires.

The mechanical properties of the cellulose acetate film make it a desirable insulating medium for very fine wires. Its elasticity permits of considerable stretching of the wire before rupture takes place, thus insuring continuous insulation between wires on the finished coil. Its specific resistance is very high, so that the film, even though thin, provides ample insulation between turns and between the layers of superposed wire, The evenness of the coating, and the regularity with which the film can be applied to the wire, are important advantages; the finished wire is free from imperfections of coating, and presents an attractive appearance.

This insulation can be colored any desired shade to harmonize with the surroundings. In case of very fine wire, a bright green makes a satisfactory color, rendering it easy for the operators to see the wire, and to detect irregularity in the winding; but if these fine wires are colored a neutral tint, they are practically invisible, and winding them is a difficult operation.

The sizes of wire best suited to this process are from 0.003 in. in diameter, or even finer, to those as large as .005 in. For larger sizes, the enamel coatings are more suitable.

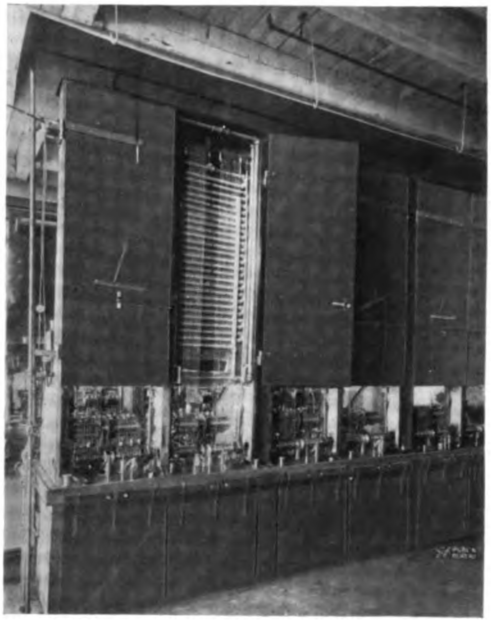

Fig. 1. Acetate Wire-Coating Machine in Operation

Cellulose acetate has been used for a number of years for the windings of meter armatures, where light weight is of great importance.

The following tabulation shows some of the more important comparisons of data:

.003 Diam. of Copper	Acetate	Single Silk	Single Cotton
Thickness of insulating film	.0005	.0009	.00175
Wire space factor	.442	.313	.167
Wt. per thousand feet (lbs.)	.033	.036	.049

With acetate coated wire the greatly improved space factor means, that for a given number of turns on a given form, the mean length of turn and total weight of wire is greatly reduced. This is shown in the following tabulation, which is drawn up on the basis of a perfect winding:

Diameter of spool	1 in.
Length of spool	1 in.
Number of turns	100,000
Diameter of copper	.003 in.

Insulation of Conductor	Outside Diam. of Coil (Inches)	Resistance (Ohms)	Wt. of Coil (Lbs.)	Price per pound to give same cost of coil
Acetate	4.20	71300	2.22	**$7.50**
Single silk	5.53	89500	3.04	**5.50**
Single cotton	9.50	144000	6.73	**2.50**

These coils are shown in Figure 3, which illustrates the great reduction in size made possible by the use of film-coated wire.

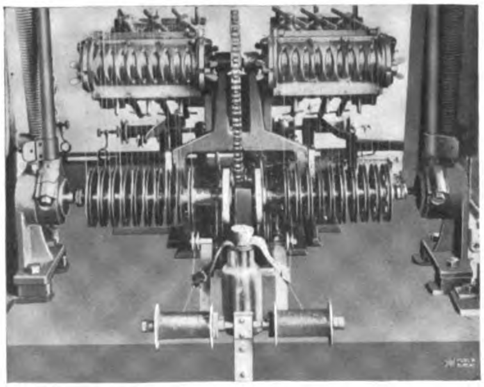

Fig. 2. Acetate Wire-Coating Machine

The great decrease in size shown in the above tabulation, would, in itself, be enough to warrant the use of acetate wire for many kinds of coils.

Another great advantage of acetate wire is that it is not affected by ordinary atmospheric conditions, whereas all fibrous materials absorb large quantities of moisture. Complete drying and impregnating processes are necessary for fibrous insulations, if long life is to be expected of them.

Manufacturers of telephones and other specialties, who use fine wires, will find film-coated wires of very great service in reducing the cost, and also the size, of their apparatus.

In the Lynn acetate wire-coating machines the solution automatically passes from the mixing reservoirs to the coating portion of the apparatus. Here, by a system of transfer wheels, the solution is applied to the revolving coating roll, which, in turn, deposits it on the moving wire. The quantity of solution placed on the wire must be adjusted to a nicety; therefore mechanical scrapers are employed, which remove the excess and leave just the proper amount to be deposited on the wire.

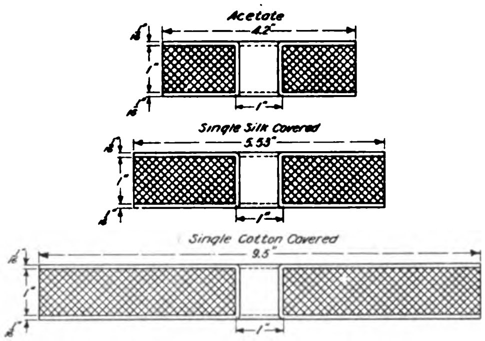

Fig. 3. Relative Sizes of Acetate Coated, Silk and Cotton Covered Coils of the Same Number of Turns

After receiving its coating of solution, the wire passes through the oven at the rate of several hundred feet per minute. The volatile solvent is here driven off and the coating hardened, after which the process is repeated until numerous coatings have been applied. This method insures an even distribution of the film over the whole surface of the wire.

To keep the fine wire moving at such a high rate of speed, a very delicate adjustment of the moving parts is required, for the slightest unevenness of motion is sure to break the wire. This is prevented by friction drives and friction tension devices, which insure a perfectly uniform motion.

THE GENERAL ELECTRIC COMPANY'S PRINTING PRESS EQUIPMENT WITH PUSH BUTTON CONTROL

By F. E. Vickers

The application of the electric drive to large printing presses requires a nicety of control which is not often needed in other lines of work. In the case of a large sextuple press requiring a 50 h.p. motor to drive, with the heavy pressure of the plates against the blankets, the dragging of the ink rollers, and the stickiness of the ink, a very large starting torque is necessary to put the press in motion; once in motion, the torque required is greatly reduced. It is necessary that the press be started off very slowly to prevent breaking the sheet, should there be a little slack between the paper roll and the cylinders, and it is also necessary that a very slow and uniform speed be maintained for perhaps two or three minutes at a time for threading in the paper. After the paper has been threaded in, a uniform acceleration of the press is necessary up to its maximum speed, as any sudden change from one speed to another is almost certain to break the sheet, causing delays as well as waste of paper.

The modern method of push button control, with push button stations located on various parts of the press for the convenience of the pressman, requires absolute reliability on the part of the push button stations, as well as upon the controller itself. This problem of electric drive has been very satisfactorily solved by the General Electric Company in a number of press equipments furnished the San Francisco Chronicle. In addition to a CLB-50 h.p. compound-wound main drive motor, and a CQ-10 h.p. series-wound auxiliary motor, these equipments include a C-30 master controller, operated from the push button stations, and the well-known Type M control contactors.

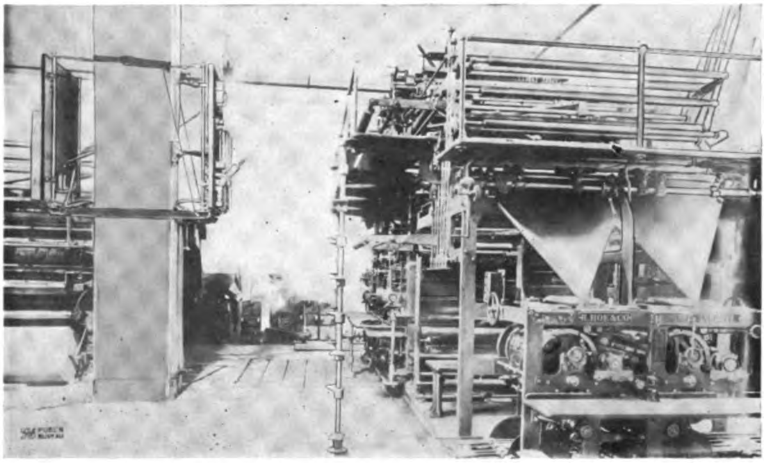

Fig. 1. Cylinder Press of the San Francisco Chronicle, General Electric Push Button Control

The sextuple Hoe presses of the San Francisco Chronicle are equipped with six or more push button stations, each push button station consisting of a "start" button for accelerating, a "slow" button for decelerating, a "stop" button for stopping the press quickly, and a "safe" and "run" switch for preventing the starting of the press when the "safe" button is in on any one of the push button stations. Also, when any "safe" button is in while the press is in operation, it is impossible to accelerate the press, but the deceleration or stoppage of the press in the regular way is not interfered with.

A solenoid-operated master controller, operated from the push button stations on the press, is mounted on a suitable switchboard panel, with an ammeter, switches, etc., and this master controller operates Type M contactors, which are mounted in the motor pit, together with the motor resistances.

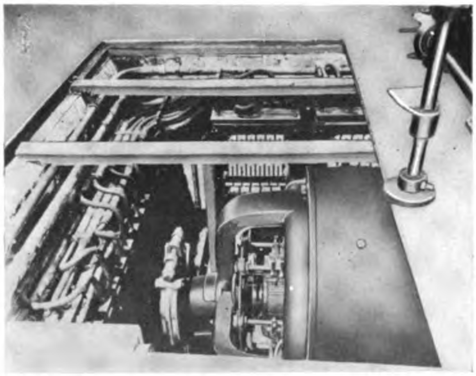

Fig. 2. Motor and Rheostats Located in Pit under Press

The main motor is geared direct to the main press shaft, and on this main press shaft is mounted a magnetic clutch, the loose portion of which is geared to the auxiliary motor, by which it is operated through a worm gear and intermediate spur gears. The auxiliary motor is series-wound, and the magnetic clutch is also in series with the auxiliary motor.

The master controller on the switchboard is so arranged that when the starting button is pressed in, and the controller is notched up to the first or second point, and the starting button then released, the controller will drop back to the off position. When notched up to the third point or beyond, it will remain stationary when the starting button is released. If the starting button be held in continuously, the controller will be slowly notched up until the motor attains its highest speed. The slowing-down button operates the controller in the same manner, but in the opposite direction, the controller slowly notching down as long as the slowing-down button is held in

The auxiliary motor is so connected on the first three controller points, that on the third point the auxiliary motor is in full operation. The main motor, being geared directly to the press, runs with the small motor, but without current. When the controller passes to the fourth notch the current is cut off from the auxiliary motor and clutch; the clutch opens and the auxiliary motor comes to rest. At the same time current is thrown on to the main motor, which then takes the load, and can be speeded up to any desired speed by notching up the controller.

A by-pass switch has been provided which permits the operation of the auxiliary motor and clutch during the upward or accelerating motion of the controller, but cuts them out of service on the return stroke of the controller, thus avoiding any danger of stripping the worm gear of the auxiliary.

On the controller panel a red signal lamp is provided, this lamp being lighted at all times when current is on either of the motors. The lamp circuit is opened when the controller is at the bottom of its stroke, and the pressmen can thus make sure at a glance that the power is off before entering dangerous places about the press.

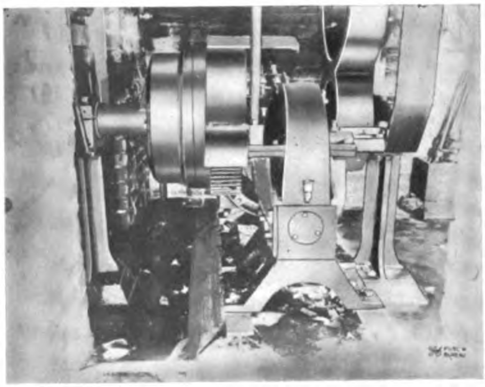

Fig. 3. Series Motor, Worm Gear and Magnetic Clutch

Where several presses in the same room are in operation at one time, it may be difficult for the pressmen to determine, from the sound of the controller, when the third point has been reached; this being the position of the controller for threading in the paper. Under these conditions, an arrangement can easily be provided to light a small signal lamp at each push button station on the press, to indicate when the controller is on the third notch, these lamps being operated through a switch which is closed only when the controller is on the third point.

The acceleration of the press is very uniform and smooth, and the breaking of the sheet has been reduced to a minimum. The auxiliary equipment is so speeded that when the pressmen wish to get a "turn-up" in order to put plates on the cylinders, they can do so by "jogging" the cylinders a half inch, or even less, with accuracy and ease. Moreover, the plate cylinders can be given a half turn, and stopped at any desired point with great accuracy, thus reducing delays in "spotting" to a minimum. The auxiliary motor gives a speed of about ten revolutions of the press cylinder per minute, which is a very satisfactory one for threading in the paper. A still slower speed can be obtained, if desired, by jogging the press along on the first and second notches of the controller.

Figure 1 shows the first press installed by the Chronicle since the great fire. A portion of the second press may also be seen in the photograph. Two controlling panels are shown mounted on a column at the left of the picture, and are so placed as to give a clearance of seven feet from the floor, in order that the floor might be left clear for the handling of paper. The column is of structural iron surrounded by brick work, and the panels are mounted on iron straps clamped around this brick work. Two push button stations are shown, one on either side of the folder of the press. The 50 h.p. main driving motor is in a pit, which is covered by the planks appearing just at the left of the press.

Figure 2 shows the 50 h.p. motor, with contactors and rheostats, in the pit beside the press.

Figure 3 shows the auxiliary equipment, which is mounted on the shaft driven by the main motor, and gives a very good view of the magnetic clutch and its brush-holders, while the worm gear and a portion of the motor are also plainly visible. The gear which meshes with the motor pinion is just through the wall shown on the left of the picture.

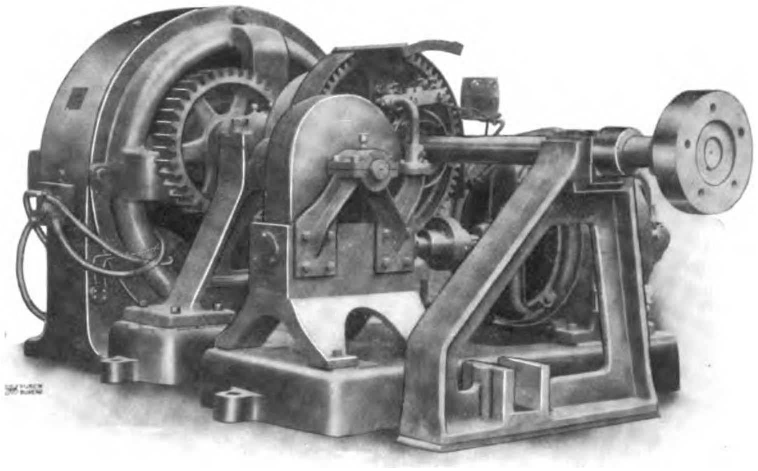

Fig. 4. Self-contained Set for Driving Cylinder Press. Push Button Control

Figure 5 shows a self-contained set for the San Francisco Examiner, consisting of a 60 h.p. main driving motor, and a 10 h.p. auxiliary motor, mounted on a common base. This differs from the Chronicle equipment in the assembly only. The entire set is mounted in a pit outside the frame of the press, and a section of this frame, included in the picture, shows the location of the apparatus with respect to the press, the coupling on the shaft being underneath the latter.

The controller has been very carefully developed, and it is thoroughly " fool-proof," so there is no possible way of causing any damage to the press or electrical equipment by pushing a wrong button. The entire outfit has proven very reliable and thoroughly satisfactory.

MILL TYPE ENCLOSED ARC LAMP FOR 220 TO 250 VOLTS D. C. CIRCUITS

By G. N. Chamberlin

Some of the most severe operating conditions met with in the field of arc lighting are found in the case of the nominal 220 volt power circuit as generally used in iron and steel mills. The varying potential of such circuits as have a large percentage of motor load, together with the high temperature, extreme vibration, and the presence of large quantities of fine metallic dust, makes it necessary that a lamp be designed specially to meet these requirements.

This new lamp, as shown in the accompanying illustrations, is of the well-known two-rod type. The lamp top is the General Electric standard casting, with large porcelain insulator suspension, such as is used for high potential series circuits. This top is equipped with large two-screw cast binding posts, each insulated with porcelain bushing, thus avoiding any possibility of grounds or short circuits from collection of metallic dust. Within the lamp casing similar precautions are also taken against grounds by the use of large lava and porcelain bushings.

The windings are of the bare wire edgewise-wound type, insulated with non-combustible material. The series lifting magnet being of copper wire, and series resistance of German silver. There being no inflammable material, the destruction temperature is the melting point of the German silver wire. This is a very important consideration in the adoption of a lamp for 220 volt circuit, as with 3.0 amperes current, there are 660 watts

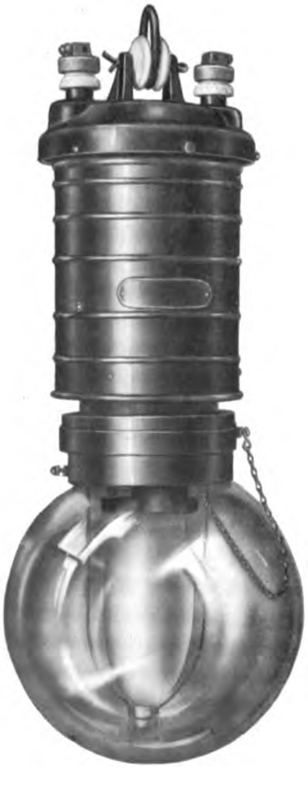

Fig. 1. Mill Type Enclosed Arc Lamp

energy to be dissipated; and with maximum current possible (short circuited arc) there are about 1800 watts energy to be dissipated. For 235 volt and 250 volt circuits the wattage is correspondingly higher.

That portion of the heat which radiates from the arc is separated as far as possible from the heat of the lamp windings which are attached to the lamp cover. An air space between the gas cap and the lamp base frame, together with the open air space between the globe ring and casing, quite effectually keep the heat of the arc away from the lamp mechanism.

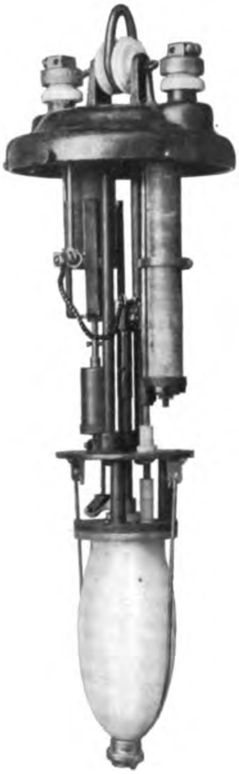

Fig. 2. Mill Type Enclosed Lamp, Casing Removed

The dashpot is the 1 in. standard graphite plunger type, equipped with a phosphor-bronze cap to exclude all dirt and dust. The placing of dashpot below and directly in line with the operating magnet, allows of large clearance between shell and plunger. This arrangement assures close current regulation, aside from being the coolest place within the lamp mechanism.

There is but one wire or lead used in the lamp, this being the German silver, glass bead insulated flexible cable connecting the magnet to the movable upper carbon holder.

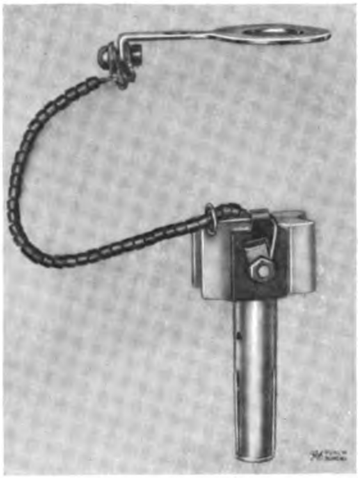

Fig. 3. Upper Carbon Holder, Cable and Terminal

Fig. 3 shows the method of attaching the cable, both to the magnet winding and the upper carbon holder. The terminals, attached without solder, and the special supports which avoid sharp bending of the cable, together with the material used, assure permanent connections.

The main body of the casing is black oxidized solid copper 7 in. in diameter. The lower portion, for supporting the globe ring, is 5 in. in diameter; thus furnishing an open space between the two for ventilation of the mechanism chamber. The increased draft, together with the large radiating surface of the 7 in. copper casing, facilitates the dissipating of a large amount of heat.

While such abnormal tests of lamps are not recommended, and at best do the lamp no good, it may be interesting to note that lamps have been connected to a 250 volt circuit with carbons short circuited for three days, 12 hours per day, and then operated normally for several weeks. Aside from a discoloration of the casing and internal parts, the lamps were in no way damaged.

While nearly all enclosed arc lamps have, in past years, been equipped with switches, it is a recognized fact that only a small percentage of these switches are ever used. Many of the larger arc lamp users are now specifying that their lamps be furnished without switches. The lamp top without switch is shown in Fig. 2, and is recommended, though the lamp can be furnished with a switch if required.

The enclosing globe support is the same, with the exception of length, as that used on standard series alternating GE lamps. It consists of a phosphor-bronze bail and phosphor-bronze spring at the bottom of the globe. The spring allows of sufficient compression to admit of the use of globes furnished commercially, and its position at the lower extremity of globes assures its remaining at a safe temperature.

Outer globe, Cat. No. 26393, globe ring Cat. No. 3568, enclosing globe No. 46, and carbons 12 in. x ½ in. upper, 4½ in. x ½ in. lower are used, these being the types used on any closed base type enclosing globe, D. C. Multiple lamps of GE standard type. Any standard combination of globes, shades, reflectors or diffusers are applicable.

A NEW SWITCH INDICATOR

By B. F. Corey

The General Electric Company has just completed the development of a new switch indicator for use in connection with automatic railway signals. This indicator, known as Type SI-104, is of a novel design which is the outcome of suggestions of well-known signal engineers who have had wide experience in the operation and maintenance of this class of apparatus. The front view of this indicator is shown in Fig. 1.

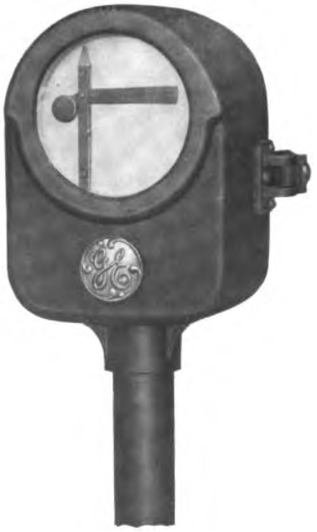

Fig. 1. Switch Indicator, Type SI-104

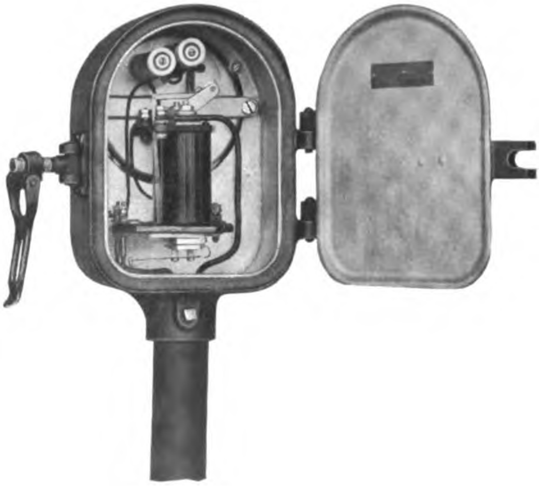

Fig. 2. Switch Indicator with Back Open Showing Mechanism

For those not familiar with this class of apparatus, it may be stated that a switch indicator is a device placed along the side of the track close to a switch, to indicate to the train crew the presence of a train in the vicinity of the switch. In case the track is clear, the operating coil of the indicator is energized, and the miniature semaphore is held in "clear" position, indicating that the switch may safely be opened. Provision must be made to open the signal circuit when the switch is thrown so as to give protection to the train which is using the switch. Such indicators are used in large numbers by railroads equipped with automatic signals.

Fig. 2 shows a back view of the SI-104 indicator, with the door open. Fig. 3 is a diagram of the internal connections. The advantages of this indicator are as follows:

With the indicator "clear," a resistance equal to double that of the operating coils is connected in series with them, thus reducing the current consumption to one-third. With the indicator at "danger," this resistance is cut out by a "back contact" carried by the armature, as shown in Figs. 2 and 3. The operating torque of the indicator is strong, and its release, effected by gravity, is positive.

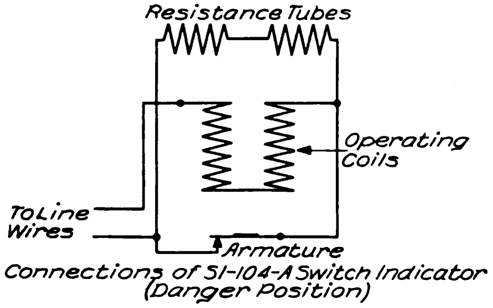

Fig. 3. Diagram of Connections

The case of this indicator is made absolutely weatherproof by means of a gasket of elastic felt surrounding the door opening. This elastic felt has proved to be far more satisfactory than the tubular rubber gaskets used by other manufacturers, as rubber deteriorates rapidly, causing a leaky joint, and is frequently torn when opening the case, due to its sticking to the cover. The case projects well over all operating parts, affording the greatest possible protection when it is necessary to open the door in stormy weather.

The connecting wire enters the bottom of the case through an insect barrier of elastic felt, similar to that used for the gaskets around the doors; while the dial is so designed that it is impossible for spiders or other insects to gain access to the blade.

The terminals are mounted on moulded insulation similar in composition to that used in General Electric signal relays. The magnets are wound with enameled waterproof magnet wire. The resistance tubes are of substantial construction.

The armature and shaft bearings are cylindrical, the journal being made of hard-drawn german silver. Provision is made inside the case for the attachment of a two-way General Electric Lightning arrester, which is furnished when required.

The indicators are manufactured with four different resistances, as follows:

Resistance of Operating Coils	Total Resistance
250 ohms.	750 ohms.
500 "	1500 "
750 "	2250 "
1000 "	3000 "

QUESTIONS

(This section is open to inquiries upon engineering subjects. The questions will be submitted to the respective departments and such as are of general interest will be answered in this column, while those of less importance will be answered by letter.)

Q. Will two 150 kw. transformers of given voltage, frequency and temperature characteristics connected in open delta on three-phase system, give 300 kw. output in three-phase current with the same temperature rise as three 100 kw. transformers of the same characteristics connected in closed delta on three-phase system? If not, what will be the difference in output at normal temperature rise?

A. Let us carry the assumption a trifle further and assume that the secondary voltage is 1000. Then, when three 100 kw. transformers are connected in closed delta, the current in each transformer is 100 amperes. The current in the line is $100 \times \sqrt{3}$, or 173 amperes Under these conditions the transformers will give normal temperature rise.

Assuming that two 150 kw. transformers are connected in open delta, the line current is, of course, the same as the above, or 173 amperes. Normal current of the transformers is but 150 amperes, and each transformer is therefore overloaded the difference between 173 and 150 amperes, which amounts to 15 per cent. The proper load for normal heating on each of the 150 kw. transformers, when connected in open delta, would be 150 kw., minus 15 per cent. or approximately 130 kw.

NOTES

EMERGENCY SHIPMENT FOR THE GREAT NORTHERN RAILWAY LINE

On Friday night, November 8th, Elevator C, one of several owned by the Great Northern Railway at Superior, Wisconsin, was destroyed by fire. On Saturday morning, when it became possible to approach the ruins, it was found that the power house which supplied electric power for these elevators had been totally destroyed, although Elevators S and X were undamaged. Owing to the near closing of navigation on the Great Lakes it was of extreme importance to the owners to get these elevators into service at the earliest possible moment.

Arrangements were made with the Great Northern Power Company of Duluth, and the Superior Water & Light Company, to furnish about 600 kw. in 60 cycle, 2300 volt current. The induction motors in the elevators were 400 volt three-phase machines, and it was therefore necessary to obtain suitable transformers for reducing the voltage. In the emergency, the Railway Company shipped to Superior the transformers which were in use in St. Paul on the transmission line between the Railway Company's Jackson Street power house and Dale Street repair shops. These were received at the Elevators by special car on Sunday morning.

Meanwhile, Mr. R. A. Swain, representative of the Power and Mining Department of the General Electric Company at Duluth, had been appealed to by the railway officials to get some transformers to replace those taken from St. Paul, in order that the Dale Street shops might not be shut down any longer than necessary.

On Saturday evening Mr. Swain telephoned the Assistant Manager of the Chicago Office of the General Electric Co., at his residence, and explained the situation; and he in turn telephoned the Sales Manager of the Transformer Department, Schenectady, who, before noon on Sunday replied that the transformers could be shipped, and that a special express car had been secured. Mr. Swain was then advised and took the matter up with the railway officials at Superior, and these in turn were obliged to telephone to St. Paul for the necessary authority. Upon receiving word that this was secured, the Assistant Manager at Chicago again got into communication with Schenectady, at about three o'clock in the afternoon, and ordered shipment. In order to load the transformers it was necessary to secure a gang of men and a train operator. These, however, were obtained, and Sunday night the special express car containing the transformers was attached to the Lake Shore passenger train No. 37, and reached St. Paul at 8 a.m. Wednesday morning, November 13th. The following day the Dale Street shops were in operation at the usual starting time.

This illustrates what can be accomplished in a real emergency, when those to whom appeal is made rise to the occasion, and the customer's interests are made paramount to personal comfort and convenience.

The Public Service Commission of the State of New York, 2nd District, have expressed their approbation of General Electric Portable Instruments, Type P-3, by placing an initial order for four voltmeters and eight wattmeters. Additional orders will undoubtedly follow as the commission extends the scope of their tests. These instruments will be used by the Inspector of the Commission as working standards to check the standards of the central station, and also in the testing of integrating wattmeters. The order was given the General Electric Company solely on the basis of merit.

* * *

Since the above item was written, an order has been received from the Commission for ten additional instruments and one potentiometer outfit.

* * *

The following letter from Mr. Boisen, of the Board of Public Works, Holland, Mich., describes a novel use made of General Electric flatiron heating units:

"We had to renew a crank pin on the high pressure side of a 500 h.p. cross-compound engine. The new pin was made 6 in. in diameter, $\frac{1}{64}$ in. taper, to be shrunk in a disk 43 in. outside diameter, 5 in. thick. To do this we had to expand the disk by heating. The engineer wanted to use blow torches below, and pieces of iron brought to a white heat in a blacksmith forge, which would burn the paint and make an all-around dirty job. Having some General Electric 6 lb. flatirons on hand, I thought it would be an easier and cleaner job to heat the disk with the heating units from the flatirons. I therefore placed a row of heating units in the 6 in. hole in the disk, and an iron core 3¼ in. in diameter in the middle to hold the heating unit in place. The current was then turned on for four hours, after which the disk was sufficiently hot. The heating units were at about white heat all the time, and during the last hour I expected to see them melt any instant; in fact, two of them did melt on one side. The brass tubing melted, but still there was no short circuit. The heating units were afterwards replaced in the flatirons, and put out in service. I have kept track of them ever since, and they have not given any trouble after three months use, one of them being in a laundry, and used forty hours a week."

* * *

SUPPLY PARTS—LYNN WORKS

The advantage of a decentralized system in a large business has been clearly shown by the reorganization of the Supply Parts business.

In 1906, 4,000,000 supply parts were shipped representing in value 6 per cent. of the entire output of the Lynn plant. This year the business has actually doubled, but notwithstanding this phenomenal increase in business, shipments are made more promptly than ever.

Six months ago the department was reorganized to the present system, where each manufacturing department carries stock, and fills its supply parts requisitions, as well as those calling for completed apparatus.

Approximately 30 per cent. of the orders are shipped the day they are received, and at least 90 per cent. of them are filled within one week's time from that date. It is anticipated that the careful study of the situation now being given the subject will still further increase this percentage.

* * *

A large single order of direct current motors and controlling equipment has recently been closed by the New York Office of the General Electric Co.

The apparatus will be installed in the Hudson Companies' Church Street terminal building.

The motors, which aggregate 635½ h.p. are, with one exception, of Type CLB; they will be used to operate ventilating fans, an air compressor and various pumps.

All of the motors had to conform to very rigid specifications, inasmuch as no part of the machine should show a temperature rise by thermometer of more than 47° C, when operating under maximum rated output at maximum speed.

Another important feature of this order is the fact that all the controlling apparatus for these motors, both automatic and non-automatic, will be of the General Electric type, instead of that named in the specifications; for the customer, after a thorough examination of General Electric controlling apparatus, decided in its favor.

The automatic controlling apparatus consists of a compound speed regulator, and automatic starting and stopping device, in connection with pressure regulator and relay, while the non-automatic controlling devices will be the standard General Electric Co. R. F. O. and S. F. O. hand-operated rheostats

PATENTS

The following Patents were issued to the General Electric Company during the months of October and November

867,415	Oct. 1,	F. W. Richey	Rail Bond
867,416	"	"	Electrical Conductor
867,456	"	W. S. Weedon	Electrode for Arc Lamps and Method of Making the Same
867,475	"	E. R. Carichoff	Motor Starting Rheostat
867,476	"	"	System of Control
867,481	"	F. P. Cox	Prepayment Meter
867,482	"	A. S. Cubitt	Locking Machanism for Controller Handles
867,486	"	S. T. Dodd	Electric Locomotive
867,496	"	H. Geisenhoner	Fuse
867,509	"	E. Johnson	Electric Switch
867,519	"	J. T. Marshall	Electric Furnace
867,533	"	H. N. Ransom	Air Brake System
867,543	"	F. H. Weston	Filling for Thermal Cut-outs
867,547	"	W. C. Yates	Starting Device for Alternating Current Motors
867,561	"	Davis & Haskins	Measuring Instrument
868,171	Oct. 15,	F. Eichberg	Control of Alternating Current Motors
868,190	"	C. D. Knight	Dynamo-Electric Machine
868,362	"	E. D. Priest	Motor-Driven Pump
868,379	"	E. Weintraub	System of Electrical Distribution
868,380	"	"	System of Electrical Distribution
868,381	"	H. E. White	Motor Control System
868,419	"	W. L. R. Emmet	Turbine Bucket
868,464	"	A. S. Mann	Control System
868,481	"	H. N. Ransom	Air Brake System
868,569	"	O. Junggren	Elastic Fluid Turbine
868,592	"	C. E. Barry	Air Brake System
868,723	Oct. 22,	D. W. Taylor	Control of Motor-Operated Doors
868,752	"	R. E. Barker	Variable Reactive Coil
868,787	"	O. Junggren	Elastic Fluid Turbine
868,889	"	R. H. Rogers	Trolley Operating Valve
869,058	"	J. G. Callan	Speed-Changing Device
869,138	"	W. L. R. Emmet	System of Lubrication for Elastic Fluid Turbine
869,185	"	M. Latour	Self-Exciting Alternating Current Dynamo
869,186	"	"	Shunt-Wound Self-Excited Alternator
869,187	"	"	Compounded Self-Excited Alternator
869,300	Oct. 29,	R. Fleming	Arc Lamp Electrode
869,301	"	"	" " "
869,314	"	C. Macmillan	Resistance Unit
869,352	"	M. W. Day	Motor Control System
869,356	"	W. Fiedler	Motor Controller
869,359	"	M. Fuss	Relay for Circuit Breakers
869,364	"	L. A. Hawkins	Air Brake System
869,365	"	"	Block Signal System
869,413	"	W. S. Bralley	Frequency Changer
869,442	"	W. D. Litchfield	Apparatus for Measuring Speed of Rotation
869,444	"	G. Macloskie	Air Brake System
869,459	"	W. B. Potter	Electric Railway System
869,464	"	G. E. Stevens	Electric Heater
869,465	"	S. B. Stewart	Third Rail Contact Shoe
871,097	Nov. 12,	M. H. Branin	Sealing-in Machine
871,160	19,	"	Stem-Making Machine
871,171	"	O. O. Kruh	Vapor-Rectifier System

General Electric Company

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Relieve electrical systems from excessive voltages incident to lightning discharges, line surges, and other line disturbances.

Its arresters are the result of the most thorough, scientific and practical investigation of high voltage phenomena ever undertaken, and arresters have been standardized for all conditions ordinarily arising in the commercial operation of lighting and power systems.

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Wrist Pin
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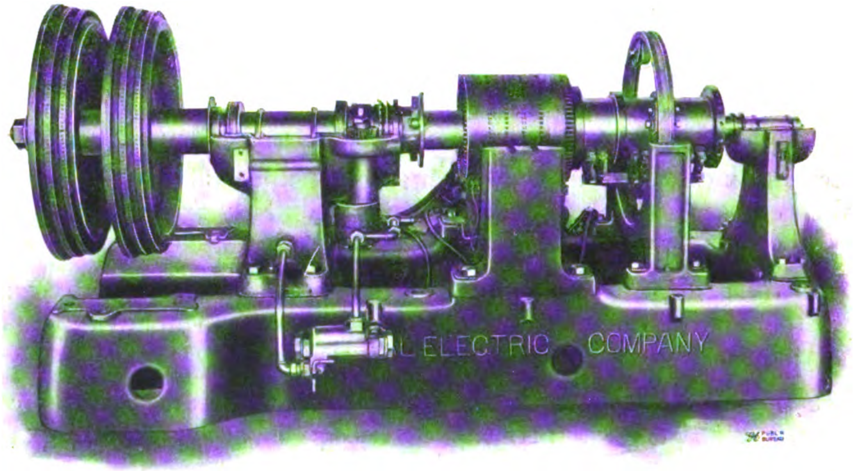

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GENERAL ELECTRIC REVIEW

VOL. X, No. 3

PUBLISHED MONTHLY BY
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SCHENECTADY, NEW YORK

FEBRUARY, 1908

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Concentrated Aurora

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Yours truly
William Thomson

VOL. X, No. 3 SCHENECTADY FEBRUARY, 1908

GENERAL ELECTRIC REVIEW

LORD KELVIN

Lord Kelvin (William Thomson) one of the greatest scientific men of the 19th century died at Glasgow, Scotland, on December 16th, 1907, at the age of eighty-three years. Like so many of Great Britain's most brilliant men, he was by birth an Irishman, and was born in Belfast on June 25th, 1824.

When William Thomson was only eight years old, his father, Dr. James Thomson, was made Mathematical Professor at Glasgow University, and the education of young Thomson was carried on in the College of Glasgow, where he won many prizes, including the University prize for an essay on the "Figure of the Earth," written when only fourteen years old. At sixteen years of age he entered St. Peter's College, Cambridge, England, but did not take his degree until 1845, when he was twenty-one years old. He was then placed Second Wrangler and also won the coveted distinction of Smith's Prizeman, which is generally considered a more noteworthy achievement. Thomson was by no means a bookworm only, but devoted himself to athletics, especially to rowing, winning the Colquhoun Sculls and rowing in his college boat when it was second on the river. He was also President of the Cambridge Musical Society.

Soon after taking his degree, he was made a Fellow of his college, and at the age of twenty-two became Professor of Natural Philosophy in the University of Glasgow, which post he occupied for the unprecedented period of fifty-three years.

Lord Kelvin was married in 1852 to Miss Margaret Crum, who died in 1870; in 1874 he was again married to Miss Frances Anna, Lady Kelvin, by whom he is survived.

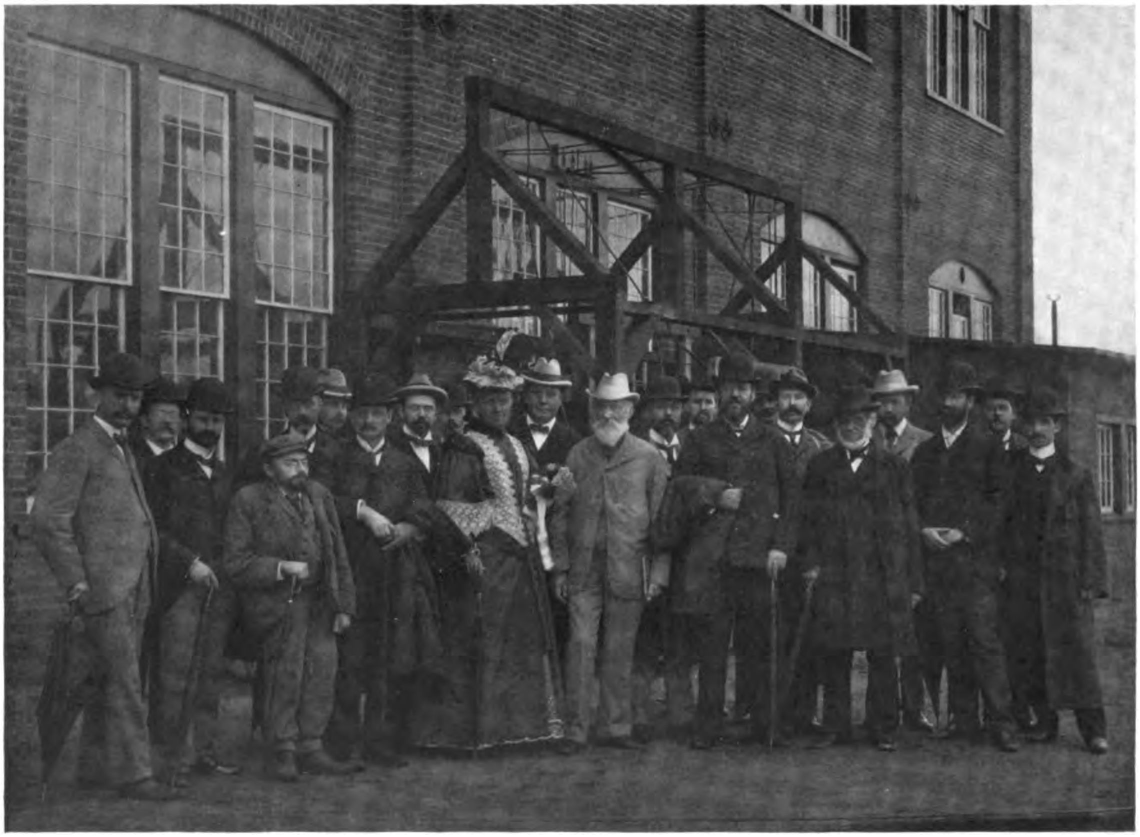
Lord Kelvin's genius was not confined to any one branch of engineering or science, and it can be truly stated that he combined in himself three different kinds of intellectual attainment, any one of which would stamp him as remarkable. He was not only a great mathematician and wonderful scientific discoverer, but also had the extremely rare faculty of applying fundamental scientific principles and recondite speculations to practical inventions; in addition, he was an acute business man. Endowed with such parts, it is not wonderful that he illuminated everything he touched, or that he enriched the human race with commercial inventions of the most epoch-making character.

Professor Thomson was knighted in 1866 by the Lord Lieutenant of Ireland for his services in connection with the laying of the first two trans-Atlantic cables completed in that year. Not only did he investigate the question of the retardation of telegraphic signals in submarine cables, enabling him to design them in the most scientific manner, but he was also the first to devise a sufficiently sensitive instrument, the mirror galvanometer, for receiving the signals. In this instrument, the operator must continuously observe a spot of light and automatic records were not possible. Nine years later Sir

William Thomson improved on his former instrument and gave the Syphon Recorder to the world, which is now practically universally used with all long distance cables. He is also responsible for many other inventions in connection with submarine cables, and he vastly improved deep sea sounding devices. In fact, he was deeply interested in all questions of navigation, partly, no doubt, owing to his being a keen yachtsman. The most fruitful result of his inventive ability in this direction was perhaps his improvement of the Nautical Compass, first patented in 1876, which was brought about by a request to write an article on this subject for *Good Words*. The type of compass which he then invented is now used almost exclusively in all parts of the world.

J. R. Lovejoy E. M. Hewlett E. A. Carolan

John McGhie T. C. Martin W. B. Potter Lord Brassey J. P. Ord



C. P. Steinmetz E. W. Rice, Jr. Gen. Eugene Griffin S. Dana Green

A. L. Rohrer G. E. Emmons Elihu Thomson Lady Kelvin Lord Kelvin Spencer Trask Alanson Trask Geo. Foster Peabody

From photograph taken at Schenectady Works of the General Electric Company, upon the occasion of Lord Kelvin's visit, September 24, 1897.

Sir William Thomson has also made many valuable inventions in reference to electrical instruments, amongst which the following may be mentioned: the quadrant electrometer, electric balances, and electrostatic voltmeters, as well as numerous types of ammeters, voltmeters and wattmeters.

Lord Kelvin was made chairman of the Board of Experts convened to study the first Niagara Falls water power scheme, and he visited the plant of the Niagara Power Company in 1897. He was elevated to the peerage in 1892, taking his title of Lord Kelvin from the name of a small stream which flows into the Clyde near Glasgow. In 1896 he completed the jubilee of his Glasgow Professorship and received a wonderful tribute of admiration and affection from the whole of the scientific world.

His work in connection with an absolute thermometric scale of temperature, and the relations existing between heat and mechanical power were of fundamental importance; and his researches into the nature of the atom, the age, constitution, etc., of the earth and tidal phenomena, by which he was led to construct a harmonic analyzer and tide-predicting machine of the highest utility, well illustrate his extraordinary versatility. With all his great attainments, he possessed a simple, loyal and generous nature, never governed by jealousy or envy; but perhaps his most wonderful attribute was his extreme modesty.

The honors both English and foreign showered on Lord Kelvin are legion. In 1893 he was elected an honorary member of the American Institute of Electrical Engineers. He was four times President of the Royal Society of London and at the time of his death was President of the English Institute of Electrical Engineers for the third time. Great Britain has now bestowed her last and crowning honor upon Lord Kelvin; he rests at the feet of Newton and next to Charles Darwin and John Herschel in Westminster Abbey.

A GAS-ELECTRIC CAR FOR RAILWAY SERVICE

BY JOHN R. HEWETT

The accompanying text and illustrations will describe a gas-electric car which has been designed by the General Electric Company to meet railway service conditions.

The car is of the combination type, and comprises one ordinary passenger compartment, a smoking room, a baggage room, an engine room, a toilet and an observation compartment. The car is single ended, having the controlling apparatus situated in the engine room. The principal dimensions are as follows:

Length over all 50 ft.

Length of engine room 9 ft., 6 in.

Length of baggage room 5 ft., 8 in.

Length of smoker 7 ft., 11 in.

Length of passenger compartment 18 ft., 6 in.

Width over all 8 ft., 8 in.

Height over all 12 ft., 10 ½ in.

Seating capacity 44.

Total weight of the car and trucks fully equipped, 31 tons.

This car was designed throughout with special reference to the service required, the main object in view being to secure a maximum carrying capacity with a minimum weight; and at the same time to have a car of great strength. The shape of the ends is parabolic, in order to reduce the air resistance to a minimum when travelling at high speed. The general shape of the car will be seen by reference to the illustration. The roof and sides are made of T irons bent to the required shape and braced diagonally. The exterior of the car is of steel plate, while the interior is finished with selected Mexican mahogany. No wood is used in the engine compartment. The floors of the passenger and baggage compartments consist of two layers of wood with paper between, armored on the under side with steel plates. The roof, which is fireproof, is of a plain oval shape; the monitor construction was not employed as it would have needlessly added to the weight. Special attention has been paid to ventilation; twelve ventilators of the globe suction pattern are furnished in the roof. The under framing is of a very rigid construction; the center sills consist of six-inch I beams, and the outside sills are six-inch channels. These are braced diagonally to lend greater rigidity.

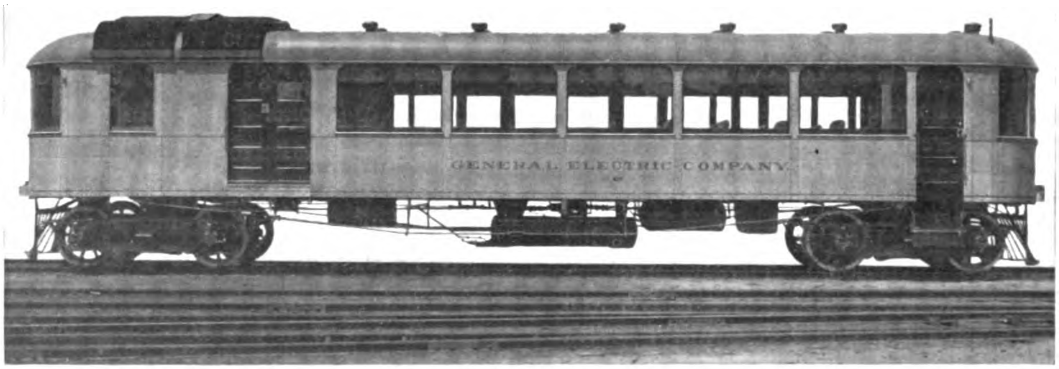


Fig. 1. Gas-Electric Car

The seats are handsomely upholstered in green leather. The interior is lighted with individual lamps, there being one light for each seat, in addition to those in the vestibule, toilet, and engine rooms; while a head light is also provided. The steps are arranged in such a manner that the bottom one folds up automatically as the vestibule door is closed.

The car body was built by the Wason Manufacturing Co., Springfield, Mass., in accordance with the designs of the General Electric Company.

The gasolene engine is direct coupled to a 90 kw. direct current generator, which furnishes current at a variable potential. This current is fed to the motor through the medium of the control system; by which the voltage of the generator may be governed according to the requirements. The two motors are of the GE-72-A Type, each rated at 60 h.p.

The engine was designed and built by the General Electric Company with special reference to the requirements peculiar to gasolene electric cars. Very special attention has been paid to the simplification of the engine; and the number of parts and weight have been reduced to a minimum.

When running at 550 r.p.m. the engine develops 100 h.p., and has a greater capacity at increased speeds. There are eight cylinders each of which is 8 in. in diameter and has a stroke of 7 in. The cylinders are placed at 90 degrees to one another, or at an angle of 45 degrees with the vertical. Each cylinder is composed of one piece, being a casting of very soft fine grain cast iron. Each casting is self-contained and includes the water jacket; it is worthy of note that special attention was paid to provide a cooling surface around the valves to eliminate any excessive temperature at the valve seats. There is one admission and one exhaust valve for each cylinder, which are arranged in such a manner as to permit the inspection of both valves by the removal of two nuts. The pistons are of the trunk type; they are made of cast iron and are rendered gas-tight in the cylinders by the provision of three split piston rings. The connecting rods, which are made of chrome nickel steel, are connected to the trunk piston by means of a hollow pin shrunk into the body of the connecting rod. The crank shaft is made in one forging of 40 carbon steel; it is a four-throw crank having an angle of 180 degrees. All of the crank pins lie in the same plane; the two center pins occupying the same angular position; while the two outside crank pins are set at 180 degrees to the center crank pins. This arrangement of cranks with cylinders set at 90 degrees to one another, gives a very satisfactory system for balancing purposes. Two connecting rods are coupled to each crank pin.

Each cylinder is fastened to the engine base by means of six bolts. The engine base proper is made of one casting of Parsons manganese bronze, the form of which is clearly shown in the illustration. The crank casing, which is made oil-tight, is of aluminum.

All of the valves, both admission and exhaust, are actuated by one cam shaft, which is driven from the main engine shaft by two gear wheels with the customary two to one reduction. This cam shaft is entirely enclosed in a circular tunnel which runs the entire length of the engine base; the tunnel is formed in the main casting. The fact that the valve rods are operated from this one shaft, has greatly simplified the design of the engine.

There are two carburetors, of the float-feed type. The ignition system is of the high tension type; a separate coil is provided for each cylinder. These coils are energized by means of a small accumulator. The sparking at the correct instant in each cylinder is effected by means of a roller commutator.

Considerable difficulty has heretofore been experienced in starting gasolene engines of this size, but in the present instance a special breech block mechanism has been provided which fires a charge of black powder into one of the cylinders, and this has proved a most effectual way of overcoming these difficulties. This piece of mechanism is illustrated by Fig. 2.

The cooling system for the cylinders operates on a thermo-siphon principle. The radiator, which is situated on the roof of the car, is divided into four separate nests of radiating tubes, these, being of the spiral-finn pattern, give a maximum cooling area per unit length.

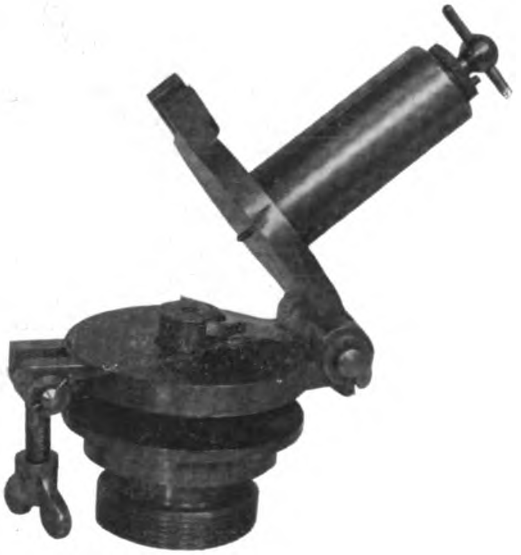


Fig. 2. Breech Block Mechanism for Starting Engine

The total cooling surface amounts to approximately 1300 square feet. Each pair of engine cylinders is connected to one nest of tubes and the four nests are in turn connected by means of three copper pipes. The water jackets are connected to the radiator by means of pipes running vertically from the engine; these pipes pass through the roof and the circuit is completed by means of other pipes leading from the radiator to the engine cylinder jackets. This system forms the most simple cooling arrangement possible, as it entirely eliminates the necessity of using pumps or cooling fans, and it has the further advantage of being easily drained and of being filled from the side of the car.

It is of interest to follow the course taken by the gasolene from the storage tank to the carburetor. The gasolene is stored beneath the car, in a large steel tank having a capacity of 90 gallons and is raised to a small auxiliary tank in the cab by means of a diaphragm pump. The gasolene is filtered in transit from the tank to the pump. This auxiliary tank is provided with a float to register the height of the gasolene, and a glass tube somewhat similiar to a sight feed lubricator is provided, so that the operator can see if the diaphragm pump is working. The gasolene is fed by gravity to the carburetors.

The oiling system has been very carefully designed. Forced lubrication is used, and for this purpose there is a nest of pumps operated from the main shaft. One pump is provided for each of the main bearings, and another oils the cams and cam mechanisms, the duty of this latter pump being to keep the cam shaft tunnel filled with oil; the oil on leaving the tunnel flows over the reduction gears and thence to the crank chamber. All of the oil used for lubricating purposes similarly flows to the crank chamber, whence it can be drained. The big ends of the connecting rods are lubricated by scoops which dip into the oil in the bottom of the crank chamber, the oil being forced

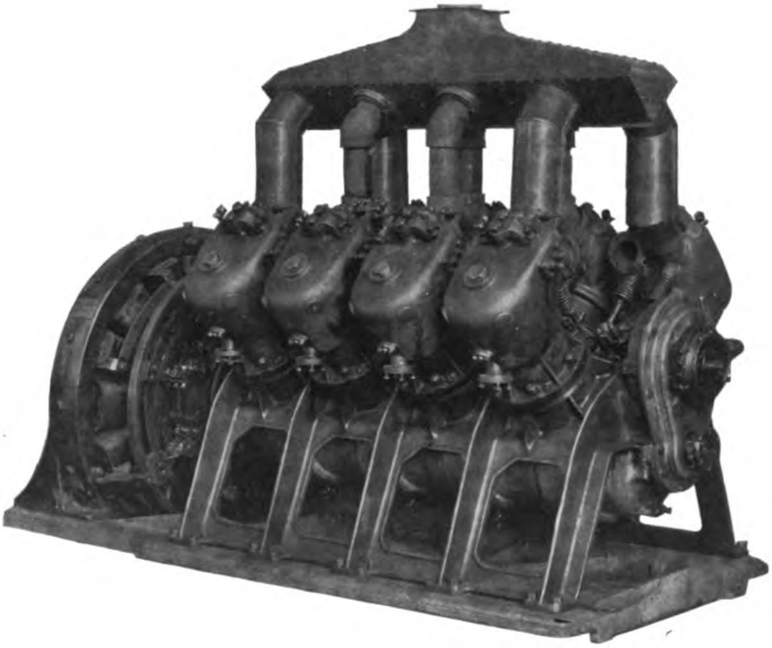


Fig. 3. GE-8-100/125-550 Gasolene Motor

to the crank pin as the crank shaft revolves.

The generator is a General Electric 90 kw., 8-pole separately-excited unit, which has been specially designed with a view to procuring the lightest possible machine for the necessary output and at the same time keeping the temperature rise to within a reasonable figure. It is provided with commutating poles, which, in conjunction with the potential type of control, gives a great flexibility of current output.

The advantage of this arrangement will be readily appreciated when it is pointed out that at starting, the field excitation is weak, and that large currents are required to give the necessary starting torque. The normal pressure when running at 550 r.p.m. is 250 volts, at which time the current amounts to 360 amperes; but at starting, a current of 800 amperes can be secured at a corresponding decrease in voltage. It would be impossible to commutate so large a current in a machine with so large a kw. capacity per lb. without the use of commutating poles.

The total weight of the generator including exciter is only 2740 lb., while a standard machine of this output weighs 8800 lb. As is only natural, in a machine where the weight has been so materially reduced, the temperature rise is higher and the efficiency lower than in standard apparatus of the same output. The higher temperatures are fully provided for by the type of insulation employed; there is no paper or muslin used anywhere in the machine. The armature coils are insulated with mica, the interpolated pole coils with asbestos, and the field coils are wound with enamelled wire. The armature leads to the commutator are riveted as well as soldered, although the precaution

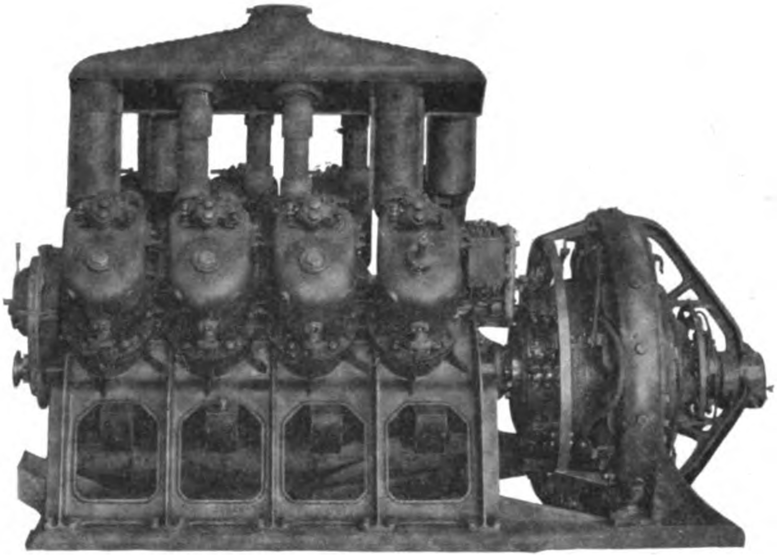


Fig. 4. GE-8-100/125-550 Gasolene Motor

has been taken to use pure tin for soldering, which has a melting point of over 200 degrees Centigrade. Air ducts of ample dimensions are provided to insure a large volume of air being circulated through the core. The efficiency is 88 per cent., being only about 3 per cent. lower than a standard machine having a temperature rise of 35 degrees Centigrade.

The exciter is a 3 kw. 70 volt, shunt-wound machine with its armature mounted directly on the armature shaft of the main generator and its field yoke supported by the bearing brackets, enabling it to fit under the back ends of the generator armature windings. The illustration of the engine, generator and exciter assembled shows far better than a written description the neatness and compactness of this generating set.

The speed of the motors is governed by a potential control, the generator being separately excited and the terminal voltage of the motors being varied by means of a rheostat in series with the exciting circuit. The simplest explanation of the controlling system is arrived at by considering the circuits separately. The armature circuit of the main generator comprises the armature, fuse, two contactors in series, reverser, and the two motors. The motors are connected in series or in parallel, according to the position of the controller handle, and they are grounded to the truck framework, while the solenoid coils for operating the contactors are energized by a storage battery floating across the field circuit. The reverser is operated as usual by a separate reverser handle on the controller.

The current from the exciter passes around the field of the main generator and through the rheostat; the function of the controller is to cut in and out this rheostat as occasion demands.

A storage battery which floats on the exciter circuit is used for supplying the lighting circuits, and its charging and discharging is controlled by means of a reverse current relay which permits of the lights being supplied directly from the exciting circuit or from the storage battery according to the voltage of the exciter circuit. A Tirrill regulator is employed for regulating the voltage on the lighting circuit. This arrangement enables the car lights to be used when the engine is at rest.

The master controller which has some unique features is of Type C-44, and gives seven steps with the two motors connected in series, and eight steps with the two motors connected in parallel. It is provided with four handles, three of which are mounted one above the other on concentric shafts. The function of the top handle is to advance and retard the ignition of the engine; the second controls the throttle of the engine; while the third handle controls the generator field resistances and the contactors, which establish the circuit for the motors, besides transposing the motor connections from series to parallel. The fourth handle operates the reversing switch and controls the direction of rotation of the motors.

The car is heated by passing part of the exhaust gases through pipes suitably located in the car body.

The car is provided with a straight air brake equipment, and the air is supplied by means of a compressor which is direct connected to the engine. The working pressure is 60 lbs. per sq. inch, and this is kept constant in the storage tank by a mechanical governor. Hand brakes are also provided.

The trucks were constructed by the American Locomotive Co. They are of the swing bolster type, and have wheels 36 in. in diameter. One motor is mounted on each truck. The journals are of the MCB standard pattern.

The interior of these cars can be designed to suit any requirements or service. Cars of this type are available for use as private cars, with sleeping and dining accommodation, as inspection cars, wrecking cars, and baggage cars, etc., etc.

ELECTRO-METALLURGY OF IRON AND STEEL

PART I

BY SAMUEL A. TUCKER
Adjunct Professor of Electro-Chemistry, Columbia University

Although a comparatively new industry, the processes for the production of iron and steel with the electric furnace have been so much perfected that it seems certain to find extended application in metallurgy. The investigation, which was made by the Canadian Government in 1904, of the processes in operation in Europe, has unquestionably done much to give a better understanding of the subject and to point out in which direction a process can best be applied from a commercial standpoint.

The methods which have so far been successful are those which effect the reduction of the ore, or produce steel, by means of heat generated electrically; and although an expensive source of heat, the fact of its application being within, and the ease of control, make it highly efficient.

The findings of the Canadian Commission have pointed to the fact that it is only profitable to smelt iron ores electrically when peculiar conditions exist. These conditions call for cheap power and localities where fuel is dear, or where the nature of the ore is such that it cannot be smelted by the ordinary blast furnace operations. But for the refining of steel in operations like the crucible process for the production of high grade steels, the electric methods can without doubt be applied to advantage.

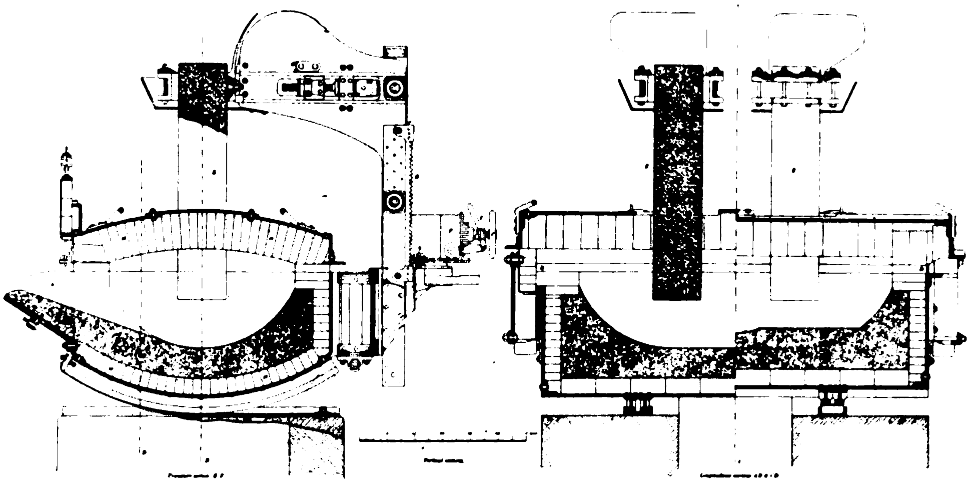


Fig. 1. Heroult Steel Furnace

How much further electricity will prove useful in metallurgical operations is difficult to say, but it must be remembered that the industry is a new one, and it seems only reasonable to suppose that as time goes on, with extended trials in actual practice, we shall have a greater application of electric methods. In some of the processes so far devised both smelting and refining may be conducted in the same apparatus; in others the intention is merely

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The author wishes to express his thanks for the use of many of the illustrations to the editor *Electro-Chemical and Metallurgical Industry*, and to Dr. Eugene Haanel's report on the commission appointed by the Canadian government.

to refine to a high grade steel, as is at present conducted in the crucible process. It will be readily understood that cheap power is of great importance to any of the processes to be described, but this does not mean that they can only be profitably applied in localities where cheap water power is available; for with the development of the modern gas engine, we have an economical source of power from the waste gases of metallurgical plants, and even where this cannot be used the gas producer can be utilized.

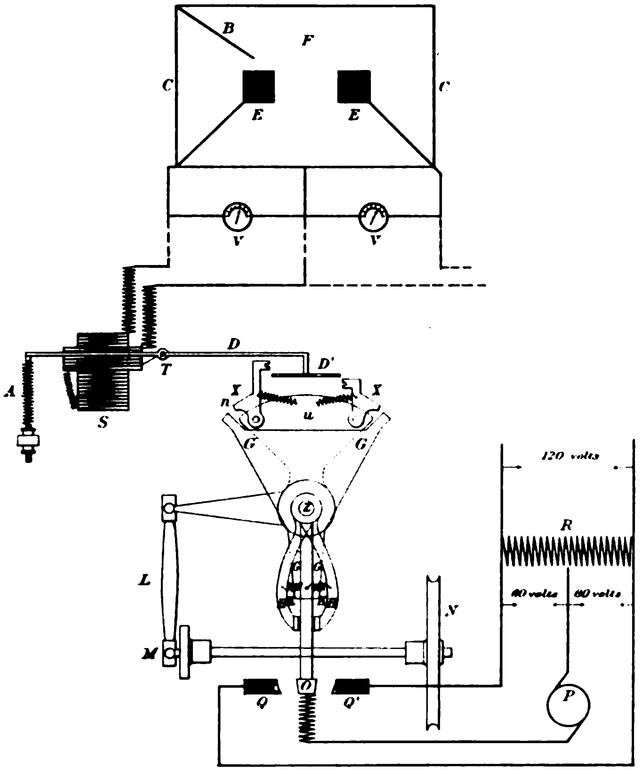


Fig. 2. Diagram of Automatic Regulator for Heroult Furnace

A further advantage gained by the electric methods in the matallurgy of iron and steel is in the production of ferro alloys of the more difficultly fusible metals, such as tungsten, titanium, vanadium and chromium. The high temperature which it is possible to reach in the electric furnace makes it possible to manufacture these alloys containing a very high percentage of the refractory metal, and to thus supply the market with the desired metal in very concentrated form.

HEROULT PROCESS

This is the invention of Mr. Paul Heroult, and was first put in operation at the Société Électro Métallurgique Française at La Praz, France.

The Furnace

This consists of a tilting arc furnace with two vertical electrodes, and is illustrated in Fig. 1, which shows a vertical and longitudinal section.

The iron casing is first lined with dolomite bricks HH, and magnesia bricks about the openings. This brick work supports the hearth K, formed of crushed dolomite, which is rammed down to the form shown.

Two electrodes EE, of about 17 in. square section and 5½ ft. long, are made of retort coke and pass vertically through the roof of the furnace. In most cases it is necessary to water-jacket the electrodes for a short distance on each side of the place where they pass through the roof.

The passage of the current is from one of the vertical electrodes, through the narrow air gap, to the slag, through which it passes to the molten bath of metal beneath, and again through the slag and the second air gap to the other electrode. It will be seen that it is very necessary to have good control of the length of the arc, which is adjusted by changing the length of the air gap. Heroult accomplishes this by having a supplementary electrode, which consists of a metallic connection between the two vertical electrodes and the bath of molten metal. A voltmeter is placed in each of these circuits, which indicates any irregularity of the two; the adjustment of the electrode being effected by hand.

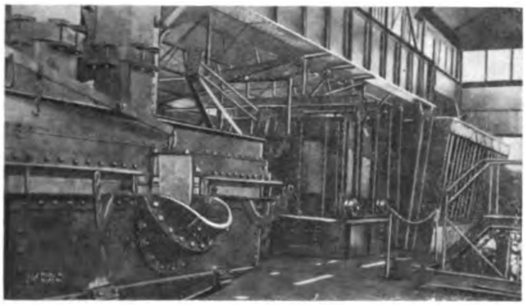


Fig. 3. View Showing Open-Hearth Furnace on the Right and Heroult Furnace on the Left.

Fig. 2 gives a diagram of the automatic regulator used to accomplish the above result. B is an iron wire connecting the casing C with the bath of molten metal. The current due to the difference of potential between the metallic bath and the electrode E, passes through the voltametric suction coil S; the movable outer coil of which (operating the rod D pivoted at T, and regulated by spring A), imparts motion to the horizontal staff D in a vertical plane with every variation of a difference of potential in the circuit. A pulley N, which is operated by a small motor, actuates the crank M, which in turn causes another connecting rod L, to oscillate the part U, which is pivoted at Z. The dogs XX attached to U partake of the oscillation of U, but in their backward and forward motion fail to clutch the staff D as long as the variation of the voltage in the circuit does not exceed two volts; when this limit is exceeded either way, D′ either rises sufficiently high, or is depressed sufficiently low to be clutched by X or by X′, respectively. When this occurs the projection *n* of the respective dog is brought into contact with the corresponding side of the triangular plate GG, to which the prongs HH, pivoted at Z, are attached by the springs KK. This results in bringing the copper piece O, the suspending rod of which is pivoted at Z, into contact with the respective carbon block Q. From the diagram it will be seen that the direction of rotation of the motor P, which raises or lowers the electrode EE, depends upon the contact made by O with either Q or Q′, and hence upon the rise or fall of the voltage in the circuit beyond the limit of two volts.

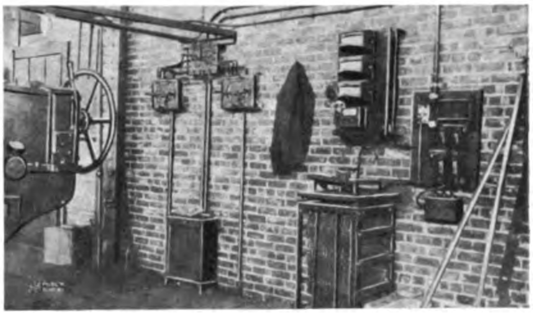


Fig. 4. Measuring Instruments and Controlling Apparatus

At La Praz an alternating current of 4000 amperes and 110 volts was used on this furnace.

The whole furnace is mounted on two rockers which are operated by hydraulic rams, or electric motor, and admits of tilting, so that the charge of about three tons may be poured. It is designed for making steel and not for the smelting of iron ores, which operation is effected in a different furnace devised by Heroult.

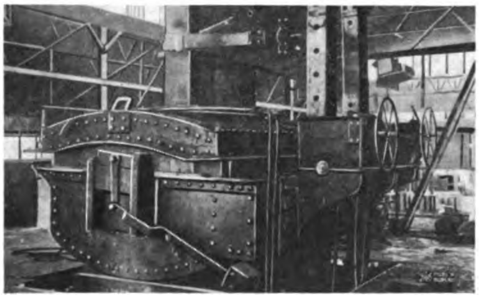


Fig. 5. Side View of Heroult Electric Furnace

The Steel Process

This consists in changing miscellaneous scrap to high grade steel, the material being usually fed into the furnace in the molten condition from a Willman furnace. A certain proportion of ore and lime is then added to produce a suitable slag, the arcs are struck, and the process carried on for a certain length of time, when the slag is removed and replaced by materials to supply a new one, this being repeated until the desired purity of the product is brought about.

Thus the production and removal of the slag is the means whereby the impurities are eliminated from the iron, the high temperature involved bringing about this result very actively. It is necessary to have the metal which is to be placed in the furnace "overblown" or suroxidized and free from slag. The metal under treatment is entirely protected from any oxidizing action of the air and from the influence of flame or gases, which fact has much to do with its resulting purity.

The proportion, composition, and number of removals of the slag depends upon the initial composition of the scrap to be treated.

The method of running for a high carbon steel, as conducted for the Canadian Commission, was as follows:

Charge:

Miscellaneous steel scrap	5733 lb.
Ferro-silicon	19 lb.
Iron ore	430 lb.
Lime	346 lb.
Ferro-manganese	3.3 lb.

Composition of scrap:

Carbon	0.110
Silicon	0.152
Sulphur	0.055
Phosphorous	0.220
Manganese	0.130
Arsenic	0.089

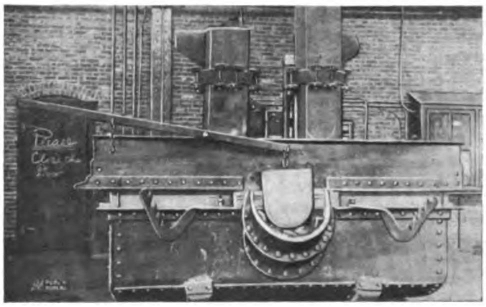


Fig. 6. Front View of Electric Furnace

Before the current was turned on, the scrap and part of the lime was charged, the remainder of lime together with the ore being added during the melting. After the charge had melted completely, a new slag composed of lime, sand and fluor-spar was added, melted and removed, after which a finishing slag was added. The time consumed was now five hours and twenty minutes, and if the product desired had been soft steel, the furnace would have been ready to tap, but in order to bring the carbon contents to the right point, "carburite," or pure iron and carbon, together with the ferro-silicon was added; another heating was then continued for one hour and twenty minutes, when the charge was poured.

The product was 5161 lb. (equivalent to 2000 lb. of steel ingots for every 2230 lb. scrap and metal charged) and had the following composition:

Carbon	1.016
Silicon	.103
Sulphur	.020
Phosphorous	.009
Manganese	.150
Arsenic	.060
Copper	Trace
Aluminum	"

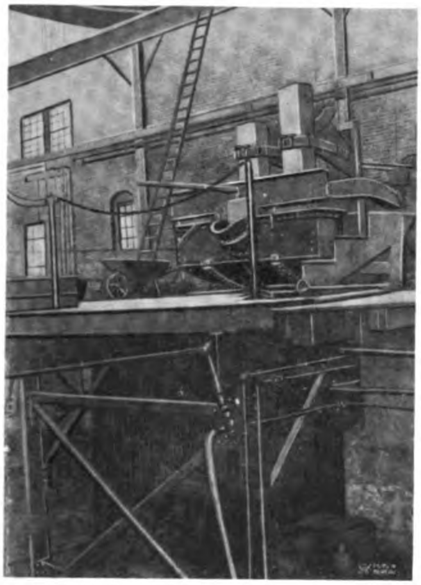


Fig. 7. View of Electric Furnace on the Platform

The energy used during the operations was 2580 kilowatt hours, which equals 0.395 h.p. years, and is equivalent to 0.153 h.p. years per 2000 lb. of steel produced. The steel thus made is uniform and compares very favorably with a high grade crucible tool steel, while the cost of production is much lower and is found to compare not unfavorably with a gas-fired Siemens furnace of the same capacity.

These furnaces may be constructed up to 10 or 15 tons capacity and would be adapted to the production of special alloy steels without difficulty.

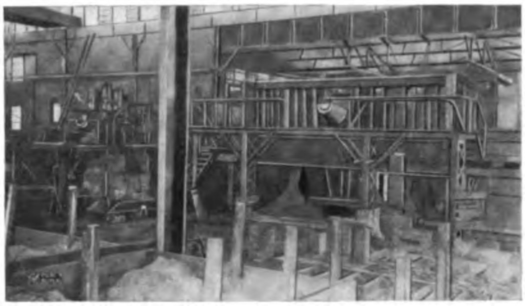


Fig. 8. General View Showing Open-Hearth Furnace on the Right and Heroult Furnace on the Left

From work which has been recently carried on with the Heroult steel process, it is found more economical to remove most of the phosphorous in the preliminary open hearth treatment. This yields a metal which is in a highly oxidized condition but which lends itself well to the subsequent changes brought about in the electric furnace. Due to the higher temperature available, a very perfect deoxidation can then be effected in the electric furnace, resulting in a very fluid slag, the lime of the slag combining with the carbon to form calcium carbide, while the sulphur is largely eliminated. Such deoxidation is nearly impossible in the ordinary furnace operations, and it is necessary that it should be brought about for the higher grades of steel. The Figs. 3, 4, 5, 6, 7, 8, 9 and 10 are views taken of a Heroult steel plant which has been established in this country.

HEROULT PROCESS FOR SMELTING ORES

This operation is carried on in a furnace of very different construction from that just described, and one which takes the form of a vertical shaft more like the early carbide furnace of Willson. When the Canadian Commission inspected the Heroult Works at La Praz, an experiment was made to demonstrate their ability to smelt iron ore directly by the electric furnace. At the time no furnace was available which was designed to meet the requirements, nor was the composition of the ore known for calculation of the necessary fluxes. With the adverse conditions existing, it is impossible, from this single experiment, to draw any conclusions of value as to the process, excepting that it was shown to be perfectly feasible to smelt iron ore direct with the electric furnace.

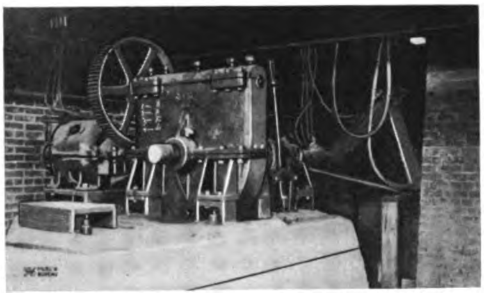


Fig. 9. Electric Motor for Tilting Electric Furnace

In order to ascertain whether the electric process could be advantageously applied to the direct smelting of ores, a series of experiments under the supervision of Dr. Eugene Haanel, were carried on in 1906 at Sault Ste. Marie, in a plant specially designed by Dr. Paul Heroult. The Canadian Government granted fifteen thousand dollars for these tests, as they had a very direct bearing on the commercial possibilities of iron metallurgy in Canada. The conditions in certain parts of that country are somewhat peculiar, from the fact that there are deposits of iron ore remote from the usual sources of metallurgical fuel, but where cheap power is available. Moreover, the quality of the ores is such as to render them unsuitable for the usual blast furnace treatment from the fact that they consist of magnetite containing a large proportion of sulphur. It was found that these ores could be smelted without difficulty in the electric furnace with very complete eliminations of the sulphur, and that charcoal and peat coke, of which there are abundant sources available, could be used as fuel.

The Furnace

This consisted of an iron casing bolted to a bottom plate of cast iron 48 inches in diameter, the bottom consisting of carbon paste supporting a fire brick enclosure constituting the crucible. (See Fig. 11.) The principal dimensions of the furnace were:

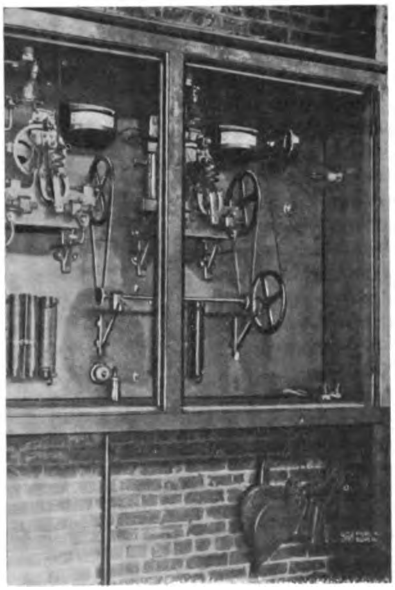


Fig. 10. Automatic Regulators for Electrodes

Diameter of bottom crucible	24 in.
Height of lower cone	11 in.
Height of upper cone	33 in.
Diameter of joint base of the two cones	32 in.
Diameter of top of furnace	30 in.

The vertical electrode was composed of specially made carbon imported for the purpose and was 16 in. square by 6 ft. long. The current was furnished by one phase of a three-phase, 400 kw., 30 cycle, 2400 volt alternator, the voltage being lowered to 50 by a 225 kw. oil-cooled transformer.

Electrical connections were made to the vertical electrode and the iron casing of the furnace by aluminum cables ⅝-inch diameter, of which 30 were attached to each of the two connections.

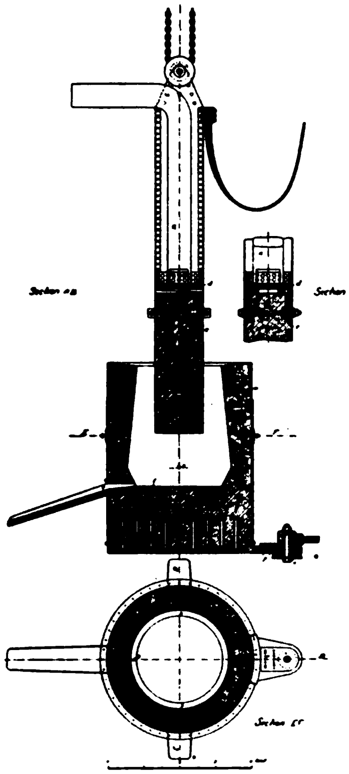


Fig. 11. Experimental Electric Furnace

Some experiments were first undertaken to see whether it was possible to utilize some of the heat energy of the fuel; for this purpose an air blast was introduced a foot below the upper level of the charge. The furnace, however, was not found to work well with this addition, and it was abandoned. With a special design of furnace it was thought that the air blast would have been a valuable addition.

The fuel at first used was coke dust briquetted with fire clay, but charcoal was found subsequently to work perfectly and to be in every way preferable. Trouble was also expected in the reduction of magnetite, which is the principal ore to be smelted, from its being an electrical conductor. No difficulty was experienced, however, in the smelting of magnetite in respect to its electrical conductivity, nor was the inductance of the furnace increased by its presence. The following is a record of a run made on magnetite from the Blairton mine.

Raw Materials

	Ore	Per Cent.
SiO_2	Fe = 55.85%	6.60
Fe_2O_3		60.74
FeO		17.18
Al_2O_3		1.48
CaO		2.84
MgO		5.50
P_2O_5 (P = 0.016%)		0.037
S		0.57
CO_2 and undetermined		5.053

Charcoal	Per Cent.
Moisture	14.06
Volatile matter	28.08
Fixed carbon	55.90
Ash	2.54

Limestone	Per Cent.
SiO_2	1.71
$Fe_2O_3 + Al_2O_3$	0.81
$CaCO_3$	92.85
$MgCO_3$	4.40
P	0.004
S	0.052

Charge	Pounds
Ore	400
Charcoal	125
Limestone	25
Sand	6

Products

Iron "Cast No. 80" grey iron

	Per Cent.
Total C	3.73
Si	3.53
S	.042
P	.034

Slag	Per Cent.
SiO_2	33.80
Al_2O_3	10.20
CaO	21.79
MgO	30.50
S	2.05
Fe	0.25
Length of run	65½ hours
Mean volts on furnace	36.03
Mean amperes	4987
Power factor	0.919
Watts 165125 or electric horse-power	221.34
Pig iron produced	11989 lb.

Output of pig iron per 1000 e.h.p. days = 9.92 tons e.h.p. year per ton of pig = 0.276.

In subsequent experiments it was found possible to smelt ores of high sulphur content not containing manganese, producing pig iron containing only a few thousandths of a per cent. of sulphur.

A further result brought out by the experiments was the possibility of smelting ores high in nickel and titanium, showing that it was quite feasible to smelt ores with the electric furnace that would be impracticable in the blast furnace.

The consumption of electrodes amounted to 17.98 lb. per ton of pig iron produced.

It is estimated that with a properly equipped plant, 12 tons of pig can be produced with 1000 e.h.p. days; and that the cost of a 10,000 h.p. plant to yield 120 tons of iron per day would be $700,000, inclusive of the charcoal plant and power plant, and figuring $50 as the cost of developing one e.h.p.

The cost of producing one ton of pig iron is figured as follows:

Ore, 55% metallic iron at $1.50 per ton	$2.70
Charcoal, ½ ton at $6.00 per ton	3.00
Electrical energy, amortization, etc.	2.43
Labor	1.00
Limestone	.20
18 lb. electrodes at 2 cents per lb.	.36
General expenses	1.00
	$10.69

From some small scale experiments made with a Heroult furnace by Albert E. Green and Frank S. MacGregor at the Mass. Institute of Technology, it was demonstrated that ores of a high titanium content (26.40% TiO_2) could be smelted with ease, producing a pig iron free of titanium. The furnace operated was of a 30 kw. capacity, and among the interesting features of the work was a determination of the temperature existing during the run. This was varied from 1375° C. to as high as 1922° C. without difficulty.

As a result of the Sault Ste. Marie experiments a Heroult smelting plant is now under construction at Welland, Ont., which will have a 3000 h.p. furnace with a capacity of 35 tons of pig per day, or of 40 tons if the hot gases are used for preheating the charge.

If this furnace is successful a larger one is to be built, together with a Heroult steel furnace, as the plant is to be used for producing steel castings. The location of this plant is not ideal from the fact that the power they will use is to be taken from the Ontario Power Co., which makes it expensive, and also because the location is removed from an ore supply. Nevertheless, the plant is expected to show economy in running even under these conditions. This will be still more convincing for electrothermic methods.

(To be continued.)

ILLUMINATION OF NIAGARA FALLS

By W. D'A. Ryan

The accompanying photographs, including that shown on the cover of this issue of the Review, illustrate some of the effects recently obtained at Niagara Falls under the rays of three powerful batteries of projectors.

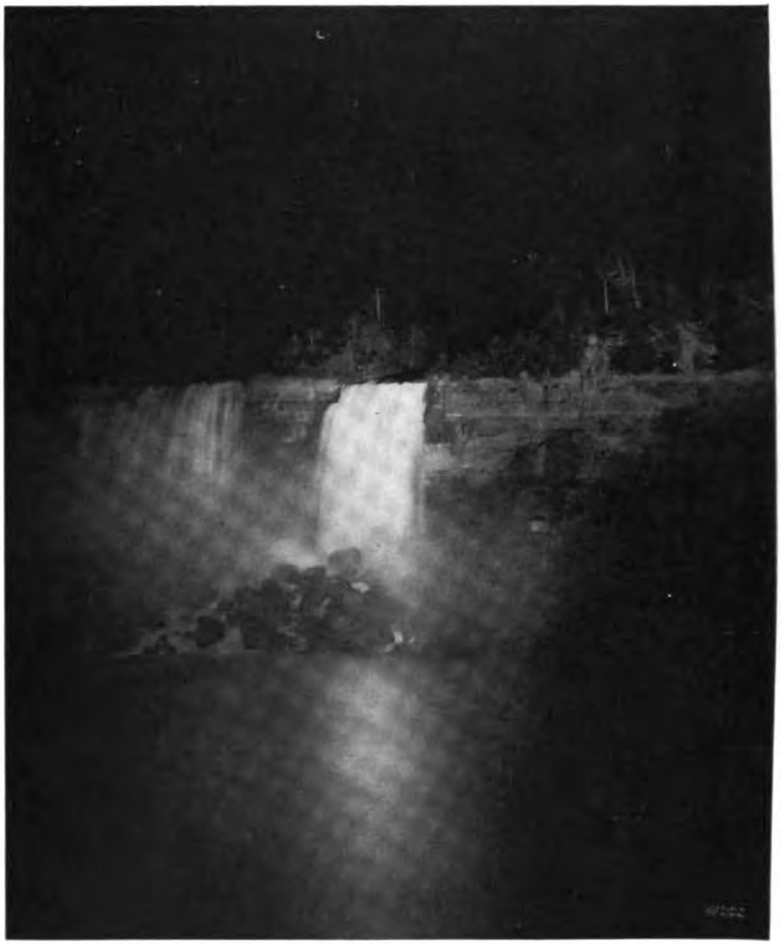


Fig. 1. Bridal Veil Falls Illuminated by Searchlight

Plans and specifications for the illumination were prepared and submitted to Mayor A. C. Douglass and a sub-committee of the Niagara Falls Board of Trade. Subsequently the project was presented to the representatives of the various railroads centering in and around Niagara.

The estimated cost of the permanent installation was approximately $40,000. Considerable apprehension was expressed as to whether or not it would be possible to illuminate the Falls in the manner represented.

Furthermore, the universal censure which would naturally follow failure or unharmonious effects approaching desecration was a serious consideration.

In order to minimize the elements of chance, the Marine Department of the General Electric Company agreed to accept a nominal rental for a thirty days trial, during which approximately one-half the proposed battery would be used, with the understanding that if the experiments were satisfactory, the balance of the apparatus would be included in a permanent installation.

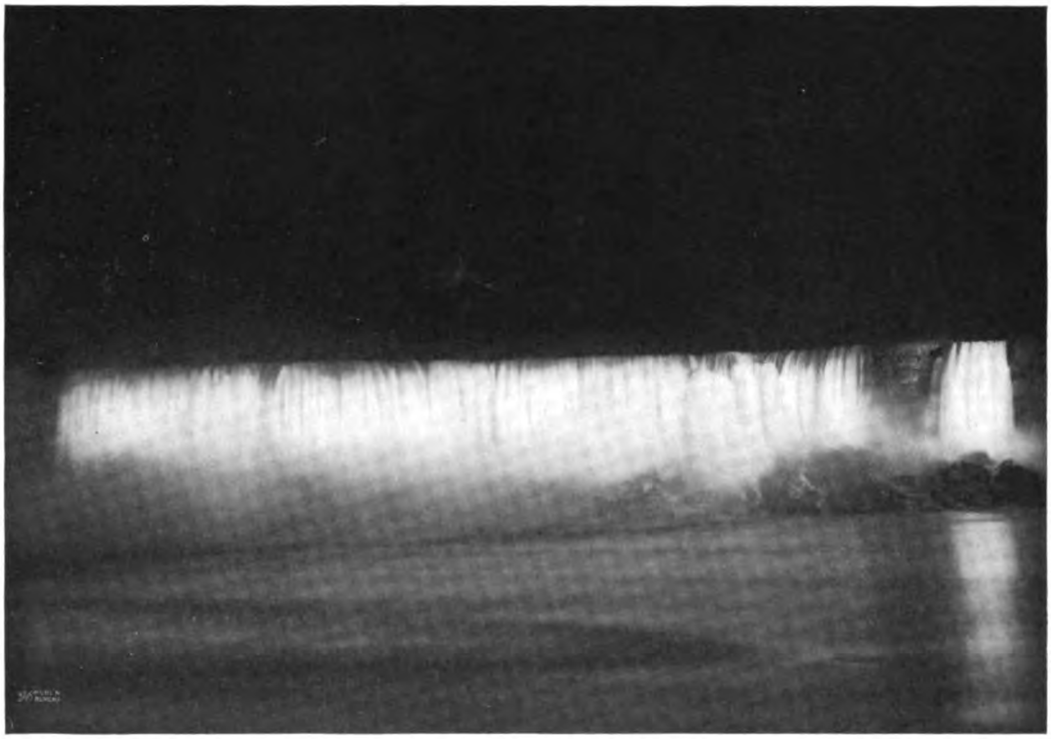


Fig. 2. Illumination of Niagara Falls from Canadian Side

Mayor Douglass personally accepted the offer, and financed the required amount by local subscription.

The projectors were installed on the Canadian side, and located in three batteries.

Battery No. 1 comprised eleven 30 in. and ten 18 in. projectors installed on a platform 250 ft. long, located in the Gorge at a point midway between the American and Horseshoe Falls, 20 ft. above the water's edge, and approximately 1200 ft. from the center of Goat Island.

Battery No. 2 consisted of four 30 in. projectors placed on what is known as the "spillway" of the Ontario Power Company, approximately 3500 ft. from the American Falls. These two batteries received current from a 300 kw. motor-generator set installed on a steel car stationed near battery No. 1.

The generator delivered 110 volts, and was driven by a 500 volt motor drawing current from the trolley circuit.

Battery No. 3 was made up of eleven 18 in. projectors located in Victoria Park, about 1500 ft. from the centre of the American Falls. The projectors at this point were arranged for series operation, and obtained current directly from the trolley circuit.

The lighting effects were controlled from battery No. 1, which was connected by telephone to the generator car and smaller batteries. The sub-division into three batteries was for the purpose of securing a wide sweep over both the cataracts, with a rising and a plunging light.

The Falls were illuminated every evening during the month of September, and while the volume of light was, as previously stated, only half the proposed strength, very good results were obtained, particularly on the American Falls. It was not possible, however, to properly illuminate both Falls simultaneously.

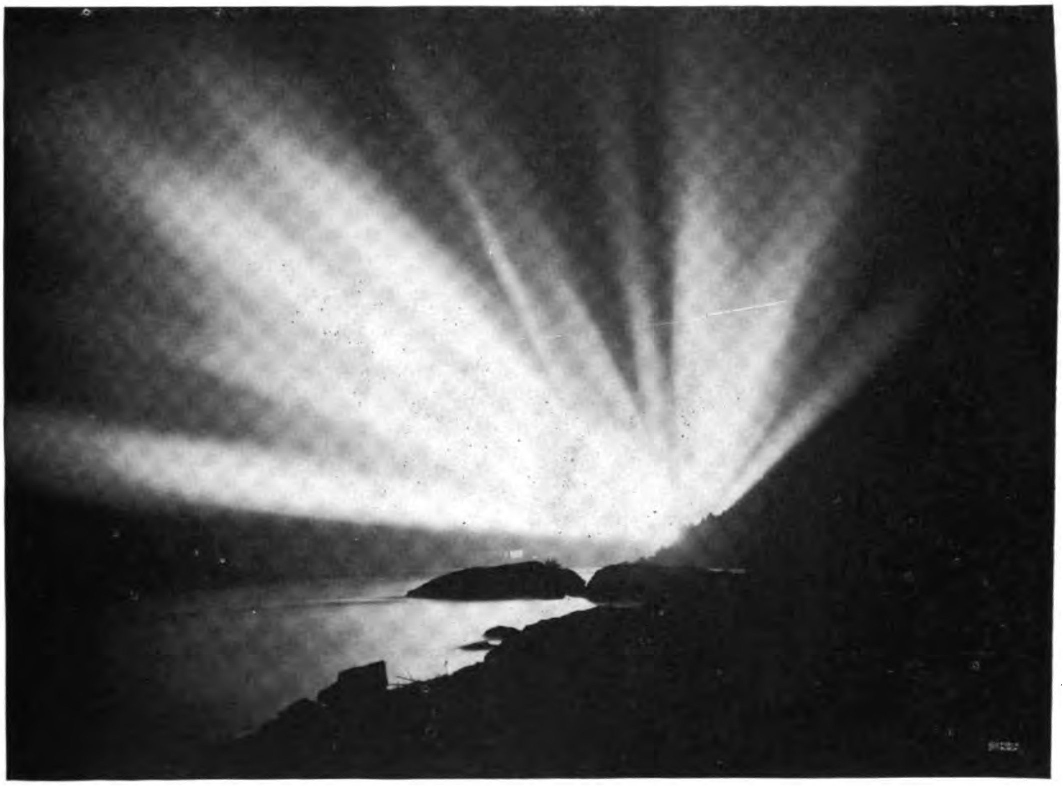


Fig. 3. Electric Aurora. Diverged

Under normal conditions, approximately 50 per cent. of the light was scattered or absorbed by the mist, and it was rarely that any discomfort was experienced in looking directly into a thirty-inch projector from Prospect Point, which was not over 2500 ft. distant. On one occasion, for a period of fifteen minutes, the light was completely shut out by the mist and rain, so that neither the Falls nor the light beams were visible. With this element to contend with, in conjunction with the enormous area over which it is necessary to evenly distribute the light, one can readily appreciate why a battery of searchlights giving approximately 2,000,000 candle-power, or practically double the amount of light used in the experiment, will be necessary to properly illuminate the American and Horseshoe Falls simultaneously.

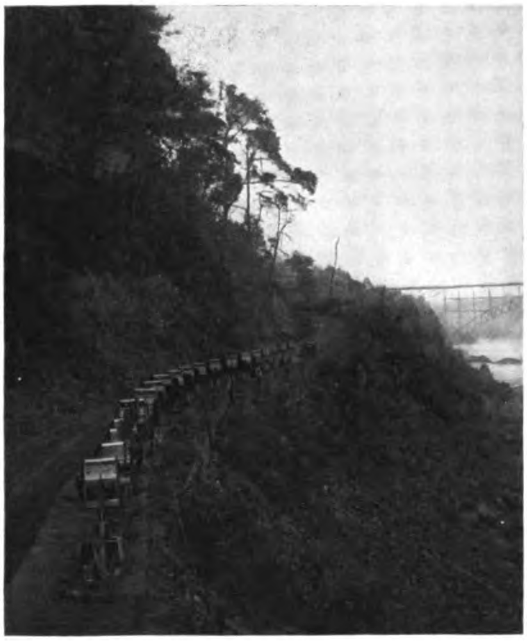


Fig. 4. Gorge Battery of Searchlights

It is the writer's opinion that the most beautiful effects were obtained by the use of white light. On this point, however, there appeared to be considerable difference of opinion. There is no question that the introduction of soft clear colors through suitable screens did not detract from the beauty of the Falls, but lent a pleasing variety of effects which appeared to be greatly admired and appreciated by the thousands of people who thronged the parks on both sides of the river every evening. An additional variation was introduced by noiselessly exploding loose giant powder in front of the main battery. This formed a blanket of pure white smoke, appearing as a cloud into which the colors were introduced. The sunset effects thereby produced in the water were beautiful beyond description.

Judging from the general comment and press reports, Niagara did not suffer from the experiments, and so pleasing were the results, as well as successful from a purely commercial point of view, that arrangements are being made to complete the permanent installation, which is expected to be in operation early next summer.

The following description of the illumination and the editorial on "Painting the Lily," appeared in the *New York Tribune* at the time of the display:

> Magnificiently illuminated, the Falls were of a beauty that their daylight aspect has never equalled. For the first time since a factory was erected to draw its power from the rushing waters the garish outlines of the bleak brick buildings were gone, and in their place, * * * were the Falls in their old glory.
>
> There was no moon when thousands of persons gathered on the Canadian side. Nothing could be seen of the Falls, but the mighty roar and the drifting spray told of their presence. Suddenly a flash shot across the river and danced for a moment alone on the American Falls before a dozen others joined it. In a moment more all the great searchlights were focused on the great mass of water, which truly shone in the light of its own glory, for it supplied the power used.
>
> Then the lights swung up to the horseshoe in a rush of prismatic color. Every hue in the spectrum was used, and words fail to describe the magnificence of the spectacle. Some feared before the trial that there was to be a desecration of nature, but the natural wonder of the Falls was simply enhanced. The sordid sight of the factories and the hurdy-gurdies of the hotels and restaurants were banished. Presently the whole great stretch of the Falls was a mass of color; the whirling water beneath was like a pool of flame in the glow of the red searchlights.

Then the lights leaped into the air, to proclaim to Buffalo, to Toronto and even Rochester, the triumph of electrical genius.

PAINTING THE LILY

Man's audacity established a new record on Wednesday night, when the electric glare of fifty enormous searchlights were turned upon the tumbling waters and rising mists of America's noblest cataract. Prior to this incident, the championship medal for nature beautifying was held, we believe, by an enterprising Bavarian who, weary of the placidity of a mountain lake near his home, installed a surf machine which cast three-foot billows sluggishly upon the unaccustomed strand. It is hardly probable that the Niagara Falls champions can retain their lead very long, inasmuch as the number of beauty doctors specializing in the treatment of nature's defects is increasing daily. It is not unreasonable to expect that some syndicate will soon be staining the upper crags and snow banks of Alpine majesties with colors more "effective" than those provided by nature. And perhaps even the thunderclaps of summer storms will some day be attuned and ordered most melodiously. All this will make many good folk weep, as the illumination of Niagara Falls has doubtless done. For is it not vanity and sacrilege to paint the lily and to add another hue unto the rainbow?

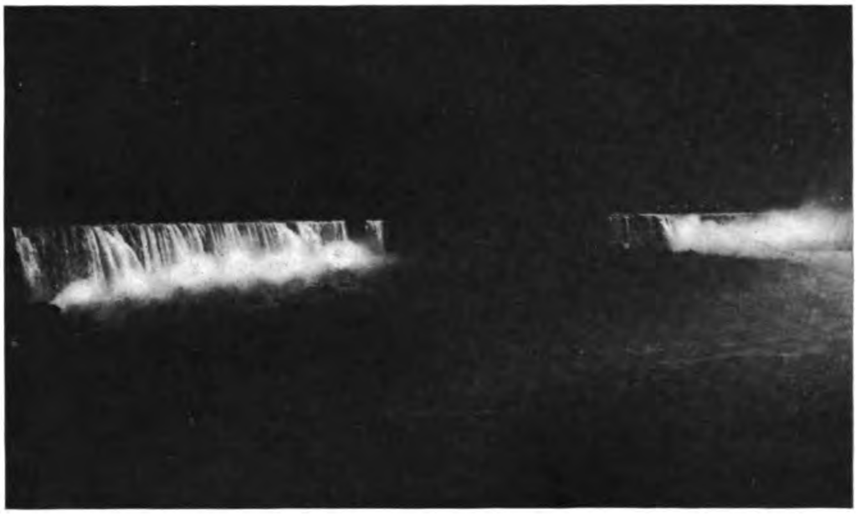


Fig. 5. Illumination of Niagara Falls. From Suspension Bridge

But was Shakespeare right? Should the beauty doctor confine his embellishing activities to warts, moles, freckles and windmill ears, leaving the muddy countenance of the Night uncleansed and the jagged faces of the mountains without titanic cosmetics? It all depends upon the skill of the beauty doctor. In Shakespeare's day, perhaps, the bard's famous lines told the truth; before the invention of the spectroscope even a good artist might have been afraid to add another hue to the visible rainbow. But any college boy today could do the job very neatly. As for painting the lily, isn't it merely a matter of method? Instead of applying white lead mixed with turpentine to the pallid blossom, as an Elizabethan decorator might have done, the modern beauty doctor applies phosphates and water to the lily's roots, and, by other indirect methods, improves the natural flower that once was thought perfect. In like manner, the searchlight has proved to be an instrument capable of lending to all of nature's mightiest monuments, save the inviolate stars, a new glory. It is said that the light effects produced upon the Falls held the thousands of spectators in almost utter silence. The nymphs of the rocky gorge and the naiads of the waters did profit, then, by the visit of the beauty doctor. Let Shakespeare continue to denounce the man who seeks "with taper light the beauteous eye of heaven to garnish." But the bard and his nature-loving disciples should absolve of sacrilege and folly all of nature's beauty doctors who are able to make more fair the face of Mother Earth.—*New York Daily Tribune.*

NOTES ON THE DETERMINATION OF RAILWAY POWER STATION CAPACITIES

PART II

By E. E. KIMBALL

The point has now been reached where one naturally asks, "Is the motor selected best adapted for the service in hand?" This can only be ascertained by determining the motor heating for the service under consideration, and it is evident that the calculations just outlined will serve to determine the heating as well as the energy consumption. The subject of motor heating has, however, been so well treated in A. H. Armstrong's papers presented before the American Institute of Electrical Engineers, June 20, 1902 and June 30, 1903, volumes 19 and 20, that it does not seem necessary to go into the method of calculating the motor capacity from the speed-time curves, but rather to include a table showing the horse-power required for cars of various weights when geared for a maximum speed of over 30 miles per hour, in order to facilitate the proper selection of motors for the service in question. The table gives the total horse-power rating of the equipment, and may be composed of either two or four motors, depending upon whether the conditions of service render it possible to run cars in trains or singly.

Table III gives a partial list of General Electric railway motors with their horse-power rating and weight, including gear and gear case, and also the weight of the necessary control apparatus. This table will be found convenient in estimating the weight of cars, after the seating capacity has been determined from the service contemplated.

It also seems advisable to include a list of various types of cars employed on American railways.

It is customary to estimate the passenger

TABLE II

HORSE-POWER MOTOR CAPACITY REQUIRED STANDARD 500 VOLT D.C. MOTORS

SINGLE-CAR UNITS

Max. Speed of Car in m.p.h.	20 Tons	30 Tons	40 Tons	50 Tons	60 Tons
30	120 H.P.	155 H.P.	190 H.P.	225 H.P.	255 H.P.
35	145 "	190 "	240 "	280 "	315 "
40	180 "	230 "	295 "	345 "	390 "
45	215 "	275 "	350 "	405 "	455 "
50	....	320 "	410 "	475 "	525 "
55	....	....	465 "	545 "	600 "
60	....	....	525 "	620 "	690 "
65	....	....	....	710 "	790 "

TWO-CAR TRAINS

Max. Speed m.p.h.	2-20 Tons	2-30 Tons	2-40 Tons	2-50 Tons	2-60 Tons
30	190 H.P.	255 H.P.	315 H.P.	375 H.P.	440 H.P.
35	235 "	310 "	390 "	470 "	545 "
40	285 "	375 "	480 "	570 "	665 "
45	335 "	445 "	560 "	670 "	775 "
50	....	520 "	655 "	785 "	900 "
55	....	....	750 "	900 "	1030 "
60	....	....	850 "	1010 "	1160 "
65	....	....	....	1140 "	1320 "

THREE-CAR TRAINS

Max. Speed m.p.h.	3-20 Tons	3-30 Tons	3-40 Tons	3-50 Tons	3-60 Tons
30	255 H.P	350 H.P.	435 H.P.	530 H.P.	625 H.P.
35	310 "	430 "	540 "	660 "	770 "
40	370 "	520 "	650 "	800 "	920 "
45	440 "	610 "	770 "	930 "	1080 "
50	510 "	700 "	900 "	1080 "	1260 "
55	....	800 "	1030 "	1240 "	1430 "
60	....	....	1160 "	1430 "	1620 "
65	....	....	1310 "	1600 "	1830 "

FIVE-CAR TRAINS

Max. Speed m.p.h.	5-20 Tons	5-30 Tons	5-40 Tons	5-50 Tons	5-60 Tons
30	375 H.P.	510 H.P.	680 H.P.	840 H.P.	970 H.P.
35	460 "	640 "	830 "	1030 "	1230 "
40	560 "	770 "	1010 "	1230 "	1470 "
45	670 "	900 "	1180 "	1450 "	1710 "
50	770 "	1070 "	1370 "	1680 "	2010 "
55	....	1240 "	1570 "	1920 "	2300 "
60	....	....	1770 "	2190 "	2580 "
65	....	....	2010 "	2480 "	2910 "

weight from the seating capacity of the car, assuming that each passenger weighs 125 lbs.

After the schedule speed, size of motors, and total weight of car has been decided upon, it is possible to calculate the energy consumption from the speed-time-energy curves plotted from the characteristics of the motor selected.

Thus the energy consumption in watt hours is equal to the sum of the product of the instantaneous values of the current and voltage divided by 3600, or is proportional to the product of the area under the ampere curve times the area under the volt curve divided by 3600. In practice it is usual to assume the line voltage constant and equal to the voltage at which the motor characteristics are correct. During acceleration a considerable portion of the energy supplied to the train or car is used up in heating the starting resistance, which loss may be determined by referring to the diagram of losses in starting resistances, Fig. 1. The figures given in this diagram represent average conditions met in direct current practice, and vary but little with the size and voltage of motors. It is assumed that the derivation of the formulae will be obvious from an inspection of the figures.

Considerable time may often be saved, and the construction of the speed-time-energy curve avoided, by remembering that for similar speed-time curves the energy consumptions in watt hours per ton mile are equal (except for slight corrections for increased or decreased train resistance, due to higher or lower speeds); also, the distances covered are proportional to the square of the linear dimensions of the speed curves.

For example: Given a speed-time curve from which the schedule speed and energy consumption for a one mile run are 24 miles per hour and 66 watt hours per ton mile respectively, find the schedule speed and average kilowatt input to car, assuming that the speed time curves are similar, and the car makes a stop every $1\frac{1}{2}$ miles. Weight of car 40 tons.

Solution:

$$\text{Time of given cycle} = \frac{3600}{24} = 150 \text{ seconds.}$$

$$\text{Time of required cycle} = \sqrt{\frac{7290}{5280}} \times 150 =$$

184 seconds.

Required schedule speed $= \frac{3600}{184} \times 1.5 =$ 29.3 m.p.h.

Average kilowatt input per cycle =

$$\frac{29.3 \times 66 \times 40}{1000} = 77.7.$$

It is quite evident that the calculations just outlined require considerably more time than is warranted in preparing preliminary estimates of the power required for the operation of proposed trolley lines. An attempt has therefore been made to tabulate the energy consumption, or rather the average kilowatt input to trains of various weights and compositions, when operating under the most favorable conditions as regards schedule speed, maximum speed and stops per mile. In other words, the short table preceding the average killowatts input to trains, shows the maximum speed for which the equipment should be geared, as well as the schedule speed obtainable with the gear ratio and frequency of stops assumed. For instance, it has been found that very little advantage is gained in schedule speed by gearing for a higher maximum than 40 miles per hour, if the stops are as frequent as one per mile. At the same time, it has not been thought necessary to include in this table the average kilowatt input to trains when geared for a less maximum speed than here shown, as it would unnecessarily complicate the table without adding greatly to the value thereof.

The *efficiency* of *acceleration* depends

TABLE III

PARTIAL LIST OF STANDARD GE RAILWAY MOTORS

Trade Name	H.P.	No. of Motors	Type of Control	Weight of Control	Weight of Motors with Gear and Gear Case	Total Weight of Equipment
GE-80	40	2	K-10	940	2800	6540
		4	K-28	1350		12550
GE-90	....	2	K-11	1015	2875	6765
		4	K-14	2250		13750
GE-202	50	2	K-36	1225	2600	6425
		4	Type M	2446		12846
GE-73	75	2	Type M	1922	4022	9966
		4	"	3158		19246
GE-204	75	2	Type M	1823	3280	8383
		4	"	3132		16252
GE-205	100	2	"	2460	3650	9760
		4	"	3600		18200
GE-66	125	2	"	2715	4376	11465
		4	"	3749		21249
GE-206	125	2	"	2460	4250	10960
		4	"	3600		20600
GE-207	150	2	"	2946	4740	12426
		4	"	4778		23738
GE-76	160	2	"	3141	5152	13445
		4	"	5385		25993
GE-69	200	2	"	3379	6230	15839
		4	"	5768		30688
GE-212	200	2	"	3379	6230	15839
		4	"	5768		30688

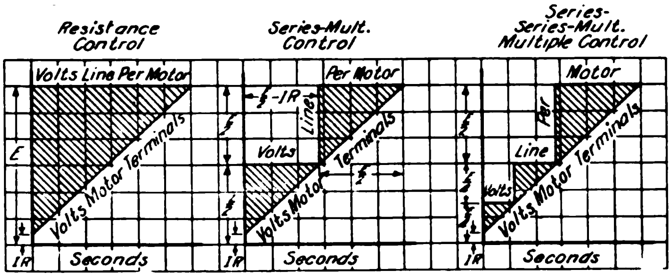
upon the ratio of the duration of control acceleration to the total time that power is on, and upon the efficiency of control, etc. The control losses are confined to the period of acceleration, which renders them of little importance in runs of considerable length, but when the runs are short, the acceleration should be higher in order that the period of acceleration may be made as short as possible and the efficiency increased. It is not wholly on account of the losses in the starting resistances that high accelerations are recommended for short runs, because it can easily be shown that the controlling factor in determining the schedule speed and energy consumption obtainable, when the stops are as frequent as one per mile, is the rate of acceleration. *

DATA ON TYPICAL ELECTRIC CARS

Type	Length Overall	Length of Body	Seating Capacity	Weight of Body	Weight of Truck	
Single truck, closed	26′	18′	18–20	6940	4400	City service
" " "	28′	20′	20–24	7600	4600	" "
" " 8 bench, open	25′	......	40	4400	4600	" "
Double truck, closed	36′	25′	35	8400	6700	" "
" " "	37′	28′	42	10350	6700	" "
" " 13 bench, open	40′	....	65	11200	11400	" "
" " closed	41′	29′	40	17000	11400	Suburban
" " "	42′	29′	40	21000	11200	Interurban
" " "	49′ 1″	39′ 8″	56	26000	16000	"
" " "	51′	42′ 7″	52	33400	21000	"
" " "	55′ 4″	45′	64	37000	16000	"
" " steel body closed	60′	50′	70	85100	21000	"
" " combination	42′ 3″	31′ 4″	....	22000	11200	"
" " "	51′	43′	40	30500	23500	"

Above weights do not include weight of motor and car equipment.

Diagram of Losses in Starting Resistances



Shaded Portions Represent Resistance Losses

	Resistance Control	*Series-Mult. Control*	*Series-Series-Mult. Multiple Control*
Ave. Rhea. Loss Per Motor Accel.	$\frac{E-IR}{2}I$	$\frac{(\frac{E}{2}-IR)^2+(\frac{E}{2})^2}{2(E-IR)}I$	$\frac{(\frac{E}{4}-IR)^2+5(\frac{E}{4})^2}{2(E-IR)}I$
Relative Rheostat Losses	100	50.3	39.7
Ave. Input to Train Per Motor	EI	$\frac{\frac{E}{2}(\frac{3E}{2}-IR)}{E-IR}I$	$\frac{\frac{E}{4}(\frac{11E}{4}-IR)}{E-IR}I$
Relative Input to Train	100	76.8	71.8
Input Per Motor	$\frac{E+IR}{2}I$	$\frac{E+IR}{2}I$	$\frac{E+IR}{2}I$
Control Efficiency	$.5+\frac{IR}{2E}$	$.65+\frac{IR}{2E}$	$.696+\frac{IR}{2E}$

IR Equals Volts Drop in Motor

Fig. 1

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* See A. H. Armstrong's paper, Proceedings of American Institute of Electrical Engineers, 1898, volume 15.

The average kilowatt input values found in the main table agree very closely with results obtained from the construction of speed-time-energy curves, and can therefore be used as a starting point in making preliminary calculations of the power required for the operation of proposed trolley lines.

TABLE IV

TRAIN INPUT—FREQUENT STOP SERVICE

TANGENT LEVEL TRACK

Stops per Mile	⅛	¼	½	1	2	3	4	5	6	7
Schedule Speed	50	40	32	24	18.5	15.5	13.7	12.5	11.7	11.0
Maximum "	65	55	45	40	30	25	23	21	20	19
Seconds Stops	30	20	15	12	10	9	8	7	6	5
Efficiency of Accel.	75	75	75	74	72	70	69	68	67	65
Accel. m.p.h. per Sec.	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7

The above data is common to all trains.

AVERAGE KILOWATT INPUT AT TRAIN

SINGLE-CAR OPERATION

Stops per Mile	⅛	¼	½	1	2	3	4	5	6	7
20 Ton Car	......	......	51	36	29	26	24	23	22	22
30 " "	......	96	69	51	40	36	33	32	31	31
40 " "	176	119	85	63	51	45	43	41	40	40
50 " "	195	130	94	73	61	55	52	50	49	49
60 " "	200	140	106	82	70	64	62	60	59	58
TWO-CAR TRAINS										
2-20 Ton	......	......	78	60	50	45	43	41	40	40
2-30 "	......	137	104	80	69	64	62	60	59	58
2-40 "	228	160	124	103	89	82	79	77	76	75
2-50 "	255	183	147	125	111	103	99	97	95	94
2-60 "	282	202	165	144	127	117	115	113	111	110
THREE-CAR TRAINS										
3-20 Ton	......	......	102	76	67	63	61	60	59	58
3-30 "	......	173	135	112	97	90	88	86	84	83
3-40 "	280	200	164	140	127	117	115	113	111	110
3-50 "	300	236	198	172	155	145	142	139	137	136
3-60 "	342	263	219	191	175	167	163	160	158	157
FIVE-CAR TRAINS										
5-20 Ton	......	......	144	124	110	102	98	97	95	94
5-30 "	......	238	196	171	154	145	142	139	137	136
5-40 "	370	292	246	216	197	188	183	180	178	176
5-50 "	438	350	302	270	250	236	228	225	222	220
5-60 "	497	400	352	314	290	280	275	271	266	263

The average kilowatts input to trains given in the above table takes no account of the loss in the low tension distributing system, substations, transmission lines, etc. These losses must be supplied by the power house, and are usually known as distribution losses. The determination of the losses depends upon combinations of the efficiencies of the apparatus forming various links in the system. Thus the efficiency of distribution for a typical interurban line may be determined as follows:

Efficiency of step-up transformers, power house	97 to 98 per cent.
Efficiency of high tension transmission line	90 to 95 per cent.
Efficiency of step-down transformers, substation	96 to 97 per cent.
Efficiency of rotary converters, substation	90 to 95 per cent.
Efficiency of secondary distributing system	85 to 90 per cent.
Net efficiency	64 to 77 per cent.
Efficiency of synchronous motor-generator sets	82 to 88 per cent.
Efficiency of induction motor-generator sets	82 to 88 per cent.

This determination of distribution losses is usually sufficient to permit of a preliminary estimate of the power required at the power house.

Main Station Capacity

To determine the capacity of the main station, it is usual to construct a train sheet which indicates the arriving and leaving time of all trains throughout the day, as well as their positions at any one time. In case of a regular schedule, it is unnecessary to show the entire train sheet, but only a section or possibly two sections showing normal and rush hour traffic. (See Fig. 2.) These sheets are usually constructed after a thorough investigation of the traffic conditions, density of population of the region served by the railway company, etc.; whereby a sufficiently frequent headway is determined to insure the greatest possible patronage, consistent with the cost of operation. From these sheets it is possible to ascertain the number of cars necessary to maintain the given headway, the load diagram showing the kilowatts required for every period during the day, the average load on the power station for 24 hours, the maximum power required, and the duration of this maximum load, etc.

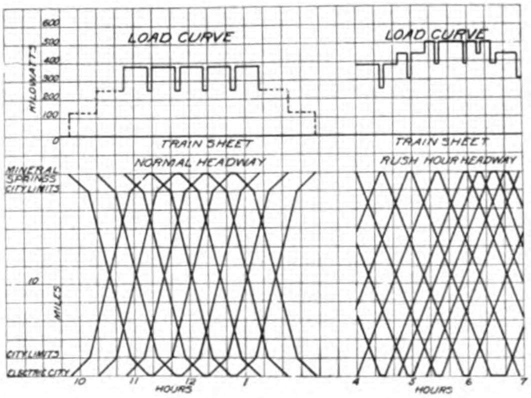


Fig. 2

The number of cars required to maintain a given headway may also be found by the following formula, without constructing a train sheet.

$$\text{No. of cars required} = \frac{\text{time of round trip, including lay overs in minutes}}{\text{headway in minutes}}$$

The load diagram is constructed by noting the number of trains on a section at any one time and multiplying by the average kilowatt input per train, as found from Table IV. The best method for constructing the load curve is to note the number of cars on a section at one time, then follow the train sheet through, noting the time when a train either enters or leaves a section, and adding or subtracting the kilowatts taken by it. The average kilowatt hours per day is proportional to the area of the entire load curve, and the average kilowatts, which usually determines the size of units to be employed, is obtained by dividing the kilowatt hours per day by the hours of operation.

The maximum average load during the day is found from the load curve during maximum traffic, and the duration of this maximum load is usually noted, as well as the value. The momentary swings of power can seldom be estimated closely, but it is customary to assume about 1½ times the kilowatts shown in the load diagram as representing the probable maximum swings at these times. This figure is equivalent to assuming one quarter of the trains on the section accelerating, and the others taking average input. For very large systems, where the number of trains is considerable, the fluctuations in load are considerably less than this amount, but on systems where the power taken by a single car represents a considerable portion of the energy required for the system, the fluctuations are much greater than 1½ times the average value shown on the load diagram. These momentary swings of power should not exceed the momentary overload guarantees of the apparatus under consideration, and as a general thing, will not be the determining factor in selecting generating units.

The generating apparatus installed in the main station should therefore be sufficient to deliver the maximum power required for the operation of the entire road, with an extra amount to be used as a reserve in case of accident to one or more of the units, or in time of excursion traffic. The proper size of units to be installed in the main station depends upon a number of other considerations, among which may be mentioned:

    Reciprocating engine
    Gas engine
    Water wheel.

1 Main Station
    Old
    New.

2 Type of Prime Mover
    Steam turbine

3. Provision for present and probable ultimate capacity of station.

4. Standard sizes of generators for direct connection to type of prime mover under consideration.

5. Efficiency of various sizes of prime movers and generators.

6. Flexibility.

7. Cost, etc.

In small installations it is usual to install two units, either of which is capable of supplying all of the power required for the operation of the road, thus providing means for transferring the load from one unit to another, for inspection and repairs. In large installations a greater number of units are installed, which enables the operation of a sufficient number during light loads to utilize the greatest maximum efficiency of the sets, and also renders it possible to reduce the reserved capacity 50 per cent. or more.

COVINGTON COKE EXTRACTOR

By M. R. Clarke

It is the purpose of this article to briefly describe one of the latest and most interesting applications of the electric motor in connection with the manufacture of coke. Electric haulage, both in the mines and in the propulsion of coke oven larries, has long been a common factor in the operation of coking plants, but there are many operations of considerable magnitude where, owing to the presence of gas in the mines, electrical power has not been used, except possibly for exterior lighting.

In the manufacture of coke, the "bee-hive" form of oven predominates. The coal is gradually converted into coke by a process of slow combustion of the volatile matter, which supplies the heat for maintaining the process of distillation. This action is conserved by the dome-shaped roof, under which the gas burns and generates heat. This heat is radiated from the dome of the oven to the mass beneath. At the end of 48 hours burning, the door in the side wall of the oven is uncovered, and the red hot coke is cooled by "quenching" with water. The coke is then a hard mass of columnar structure, and from three to four hours manual labor is required to break this apart and convey it from the interior of the oven.

It has long been the desire of coke operators to secure a machine which will displace the arduous and time-consuming hand labor required to draw an oven. The Covington extractor, manufactured by the Covington Machine Co., Covington, Va., is the successful survivor of various ingenious and powerful machines contrived to remove coke from a "bee-hive" oven.

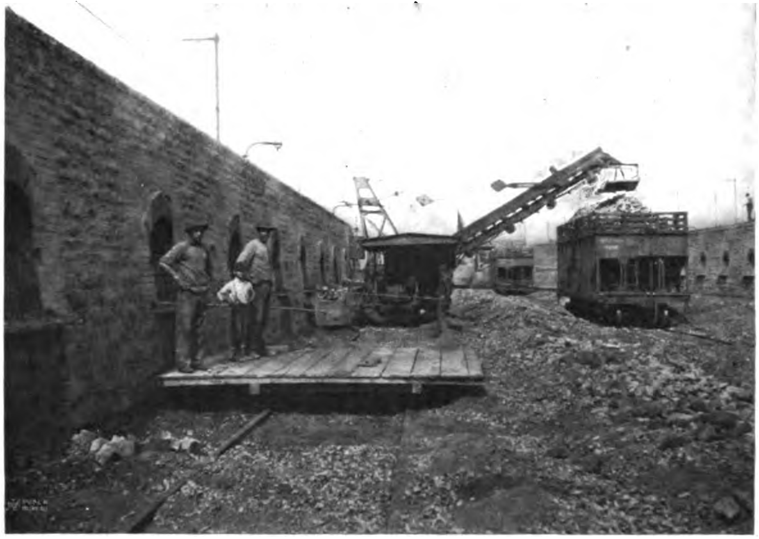


Fig. 1. Covington Coke Extractor drawing Coke from "Beehive" Oven and loading into Car. This Illustration shows arrangement of Ovens at Typical Machine Plant

In the successful operation of a machine for drawing coke from the oven, electric drive is essential, on account of its flexibility in application and control. The pronounced success achieved by the Covington extractor has created a demand for electrical generating and motive equipments for a class of operations that otherwise might dispense with electrical apparatus altogether.

The Covington extractor consists essentially of a ram, armed at its extremity with a wedge having its lower side resting on the oven floor, and its thin end extending toward the face of the coke. Pressure on this ram forces the wedge under the coke, detaching it and causing it to fall back of the ram head. On the return movement, the vertical rear face of the ram head serves as a rake, drawing the coke from the oven. It will be noted from the cut that the ram arm is provided with a rack on one side. A cut steel pinion, driven through intermediate gearing by a CO-2002, 20 h.p. enclosed series motor, operates this portion of the mechanism. An R-28 controller, with 5 points forward and reverse, and reversing with a single handle, provides an effective control. The angular position of the ram advance is controlled by a handwheel, which pivots the ram guide about the pinion center. This enables the ram to traverse every part of the oven.

It will be noted from Fig. 1 that the coke drawn from the oven drops into a trough which is parallel with the oven wall and supported by the framework of the machine.

A conveyor chain, traveling at the bottom of this trough, carries the coke to the lifting conveyor, which then lifts it to a point above the car, where it is dropped into a trap. This trap at regular intervals of accumulation, drops the coke in bunches into the car. This method of loading has been found to insure a minimum amount of breakage. The operation of the conveyor system is effected by a CQ 15, 15 h.p. slow speed, compound wound motor.

The various parts of the apparatus are mounted together on a substantial truck, which is propelled parallel to the oven wall on a standard gauge track. This propulsion, occurring while the machine is idle, is effected by a clutch which detaches the motor from the ram and applies it to the axles of the truck.

The entire electrical equipment of these machines is supplied by the General Electric Company. There are now some 150 in operation, and new machines are daily being placed in service.

The main economy resulting from the use of the coke extractor is the saving of the expense of maintaining the large force of laborers necessary to draw ovens by hand. The following is a conservative estimate of the cost per oven for machine drawing:

Drawing	14 cts.
Cleaning out	5½ cts.
Watering	6 cts.
Leveling new charge	15 cts.
Total	40½ cts.

Allowance for repairs and other items brings this total up to about 52½ cts. per oven for machine work, which is a conservative figure. The average cost of hand drawing amounts to $1.17. The number of ovens drawn by one machine in a day varies from 35 to 50. The average amount of time required to draw an oven is about 20 minutes, whereas, with hand drawing, 3 to 4 hours are necessary.

Due to the rapidity of machine drawing, the oven walls have less opportunity to cool, and a larger amount of residual heat remains in the oven to ignite the new charge of coal. Each charge will therefore have a few more hours to burn, due to the saving in time, thus producing a more complete separation of the fixed carbon and the volatile matter.

In the construction of a bank of coke ovens it has formerly been the custom to place the ovens on an elevated masonry foundation. This foundation, or "wharf wall," is arranged to be on a level with the tops of the railroad cars in which the coke is to be loaded. This arrangement is necessary in a plant where the ovens are drawn by hand, in order that the laborers, gathering the coke in front of the ovens, may be able to dump their wheelbarrows into the car. With the advent of a successful extractor, a large number of new plants have taken full advantage of the conveyor system, and have dispensed with the construction of the wharf wall, the coke being loaded directly into the cars by the conveyor. The saving effected in being able to dispense with the construction of a wharf wall practically halves the cost of building a bank of ovens. Fig. 2 illustrates the use of a Covington extractor in a typical "machine plant," where the oven walls are built on ground which is level with the railroad track.

The ever-present shower of dry coke dust has rendered it necessary to totally enclose both motors, in order to prevent the accumulation from forming "grounds," coke dust being both an abrasive and an excellent conductor.

The motor equipment of these machines is giving excellent results, and this, too, in the face of extremely severe conditions. Every effort has been made to render the control equipment as simple and effective as possible. The starting rheostats of the conveyor motors are wired in accordance with the "BTH" method, which effectually prevents the field "kick" from breaking down the armature insulation, a phenomenon which quite frequently occurs where shunt or compound wound motors are operated on a grounded circuit. The rapidity with which the machine drivers handle the controller of the ram motor is rather astounding at times, but the endurance of the motor seems to be up to the usual standard, notwithstanding the unusually severe treatment they receive.

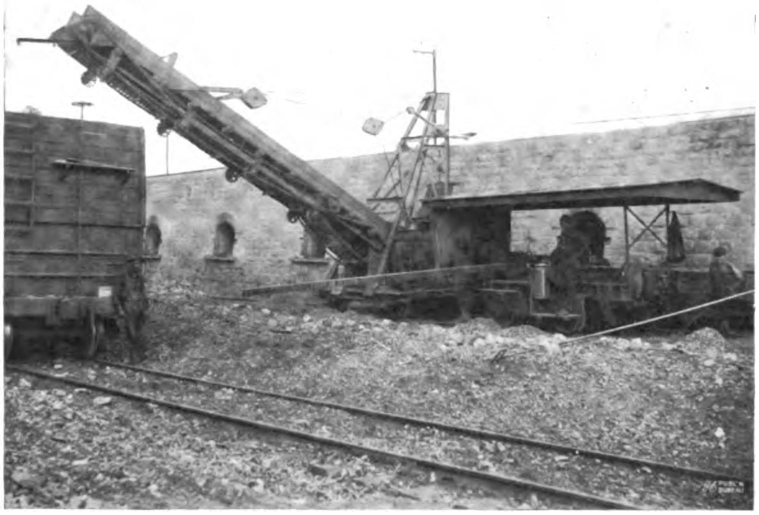


Fig. 2. Rear View of Covington Coke Extractor, Showing Controller for Ram, and Handwheel for Varying Angular Position of Ram Travel

THE ROTARY CONVERTER

PART II

By E. J. BERG

In order to study the distribution of heat in individual coils of the armature, the following arithmetic method has been used: The armature will be assumed moving in intervals covering 7.5° in space. The original position will be that indicated in Fig. 4, when the alternating current is maximum. The next position will be designated by $\phi = 7.5°$, in which case the alternating current is $i_{max} \cos \phi$, etc. The direct current is $-i_c$ on the right-hand side of the center line, and $+ i_c$ on the left-hand side.

$\phi = 0°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current^2	Σ Current^2
1	$-i_c$	i_{max}	$i_{max}-i_c$	.111 i_c^2	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	.89 i_c^2
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 7.5°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current^2	Σ Current^2
1	$-i_c$	.991 i_{max}	.991 $i_{max}-i_c$	.102 i_c^2	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	
4	"	"	"	"	.816 i_c^2
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 15°$

Coil	D.C Amp.	A.C Amp.	Resultant Amp.	Current^2	Σ Current^2
1	$-i_c$	966 i_{max}	.966 $i_{max}-i_c$	.084 i_c^2	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	671 i_c^2
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 22.5°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current^2	Σ Current^2
1	$-i_c$	.923 i_{max}	.923 $i_{max}-i_c$	.0529 i_c^2	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	.423 i_c^2
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 30°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current^2	Σ Current^2
1	$-i_c$	.867 i_{max}	.867 $i_{max}-i_c$	.0256 i_c^2	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	.205 i_c^2
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 37.5°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current^2	Σ Current^2
1	$-i_c$	.792 i_{max}	.792 $i_{max}-i_c$	.003 i_c^2	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	.024 i_c^2
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 45°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current^2	Σ Current^2
1	$-i_c$	.707 i_{max}	.707 $i_{max}-i_c$	.003 i_c^2	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	.024 i_c^2
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 52.5°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current^2	Σ Current^2
1	$-i_c$	.607 i_{max}	.607 $i_{max}-i_c$	.036 i_c^2	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	287 i_c^2
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 60°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$-i_c$	$.5\ i_{max}$	$.5\ i_{max}-i_c$	$.111\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$.89\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 67.5°$

Coil	D.C. Amp	A.C. Amp	Resultant Amp.	Current²	Σ Current²
1	$+i_c$	$.38\ i_{max}$	$.38\ i_{max}+i_c$	$2.27\ i_c^2$	
2	$-i_c$	$.38\ i_{max}$	$.38\ i_{max}-i_c$	$.244\ i_c^2$	
3	"	"	"	"	
4	"	"	"	"	$3.97\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 75°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$+i_c$	$.259\ i_{max}$	$.259\ i_{max}+i_c$	$.181\ i_c^2$	
2	"	"	"	"	
3	$-i_c$	"	$.259\ i_{max}-i_c$	$.427\ i_c^2$	
4	"	"	"	"	$6.18\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 82.5°$

Coil	D.C Amp	A.C. Amp.	Resultant Amp	Current²	Σ Current²
1	$+i_c$	$13\ i_{max}$	$13\ i_{max}+i_c$	$1.37\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	$-i_c$	"	$13i\ _{max}-i_c$	$683\ i_c^2$	$7.51\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 90°$

Coil	D.C Amp	A.C. Amp	Resultant Amp	Current²	Σ Current²
1	$+i_c$	0	i_c	i_c^2	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$8i_c^2$
5	$-i_c$	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 97.5°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$+i_c$	$-.13\ i_{max}$	$-.13\ i_{max}+i_c$	$.683\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$7.52\ i_c^2$
5	"	"	"	"	
6	$-i_c$	"	$-.13\ i_{max}-i_c$	$1.37\ i_c^2$	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 105°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current
1	$+i_c$	$-.259\ i_{max}$	$-.259\ i_{max}+i_c$	$.427\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$6.18\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	$-i_c$	"	$-.259\ i_{max}-i_c$	$1.81\ i_c^2$	
8	"	"	"	"	

$\phi = 112.5°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$+i_c$	$-.38\ i_{max}$	$-.38\ i_{max}+i_c$	$.244\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	
4	"	"	"	"	$3.97\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	$-i_c$	"	$-.38\ i_{max}-i_c$	$2.27\ i_c^2$	

$\phi = 120°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$+i_c$	$-.5\ i_{max}$	$-.5\ i_{max}+i_c$	$.111\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$.89\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 127.5°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$+i_c$	$-.607\ i_{max}$	$-.607\ i_{max}+i_c$	$.0362\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$289\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 135°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$+i_c$	$-.707\ i_{max}$	$-.707\ i_{max} + i_c$	$.0036\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$.029\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 142.5°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$+i_c$	$-.792\ i_{max}$	$-.792\ i_{max} + i_c$	$.003\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$.024\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 150°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$+i_c$	$-.867\ i_{max}$	$-.867\ {}_{max} + i_c$	$.025\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$.200\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 157.5°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$+i_c$	$-.923\ i_{max}$	$-.923\ i_{max} + i_c$	$.053\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$.423\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

$\phi = 165°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$+i_c$	$-.966\ i_{max}$	$-.966\ i_{max} + i_c$	$.084\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$.671\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	.	"	"	

$\phi = 172.5°$

Coil	D.C. Amp.	A.C. Amp.	Resultant Amp.	Current²	Σ Current²
1	$+i_c$	$-.991\ i_{max}$	$-.991\ i_{max} + i_c$	$.102\ i_c^2$	
2	"	"	"	"	
3	"	"	"	"	
4	"	"	"	"	$.816\ i_c^2$
5	"	"	"	"	
6	"	"	"	"	
7	"	"	"	"	
8	"	"	"	"	

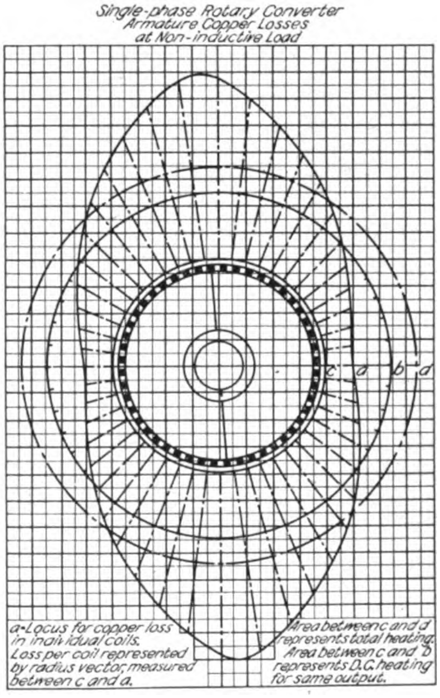

Single-phase Rotary Converter
Armature Copper Losses
at Non-inductive Load
c
a
b
d
a-Locus for copper loss in individual coils. Loss per coil represented by radius vector, measured between c and a.
Area between c and d represents total heating. Area between c and b represents D.C. heating for same output.

Fig. 5

The sum of the instantaneous losses at different positions of each individual coil is directly obtained as follows:

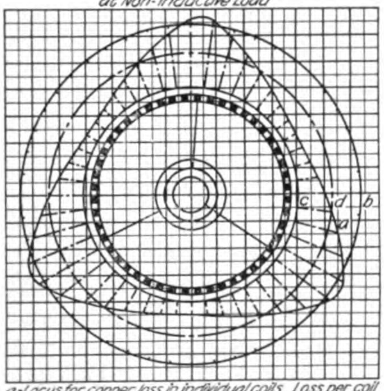
Coil No. 1	$8.75\ i_c^2$
" No. 2	$6.72\ i_c^2$
" No. 3	$5.34\ i_c^2$
" No. 4	$4.65\ i_c^2$
" No. 5	$4.65\ i_c^2$
" No. 6	$5.34\ i_c^2$
" No. 7	$6.72\ i_c^2$
" No. 8	$8.75\ i_c^2$

In a direct current generator, the loss in each coil would obviously be

$$\frac{180}{7.5}\ i_c^2 = 24\ i_c^2$$

Thus the coils nearest to the collector leads are subjected to the greatest loss; being, in this case, 1.87 times the loss in the coils midway between the leads, and about 36.5 per cent. of that in a corresponding direct current generator.

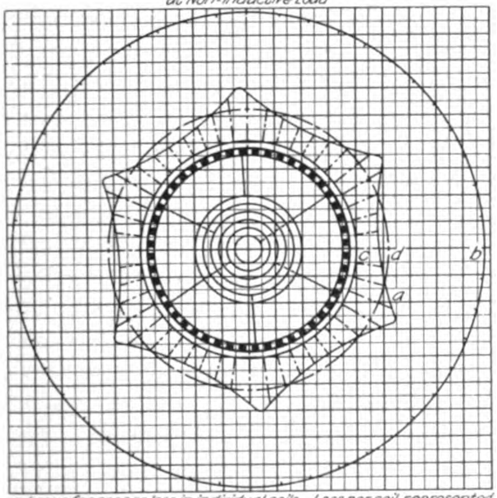
Three-phase Rotary Converter
Armature Copper Losses
at Non-inductive Load



a-Locus for copper loss in individual coils. Loss per coil represented by radius vector, measured between c and a.
Area between c and d represents total heating.
Area between c and b represents D.C. heating for same output.

Fig. 6

Six-phase Rotary Converter
Armature Copper Losses
at Non-inductive Load

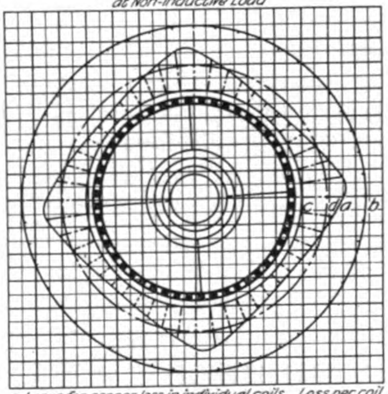


a-Locus for copper loss in individual coils. Loss per coil represented by radius vector, measured between c and a.
Area between c and d represents total heating.
Area between c and b represents D.C. heating for same output.

Fig. 7

Figs. 5, 6, 7 and 8 have been drawn to show how, with non-inductive load, the copper losses are distributed around the periphery of a single-phase, three-phase, four-phase and six-phase rotary converter, respectively. Fig. 5 refers to a single-phase converter, where the heating of the coil adjacent to the collector ring leads is about six times as great as in coils midway between the leads. The total heating is 1.43 times that of a direct current machine of the same rating; therefore, for the same degree of heating, such a rotary converter can be rated at only 84 per cent. of its direct current output as a generator. The maximum current at any time for a given load is three times that corresponding to the direct current.

Two-phase Rotary Converter
Armature Copper Losses
at Non-inductive Load



a-Locus for copper loss in individual coils. Loss per coil represented by radius vector, measured between c and a.
Area between c and d represents total heating.
Area between c and b represents D.C. heating for same output.

Fig. 8

The curve sheets are self-explanatory, and show in a general way that the larger the number of phases, the less the total heating, and the less the difference in temperature between different coils.

(*To be continued.*)

SOME NOTES ON WIRING AND WIRING SUPPLIES FOR MINING SERVICE

By F. A. Barron

In deep shaft mining operations there are several systems of power transmission in general use; among these may be mentioned:

First, a copper wire transmitting electricity to electric motors;

Second, a flexible hose carrying air under pressure to air motors;

Third, iron pipes carrying steam under pressure to steam engines.

In some mines electricity is used for all important purposes; while in others it will be found that ropes or mules are used for haulage, and steam for all other purposes; while in still others, compressed air is used for coal drilling, and electricity for all other purposes.

In each case the result to be accomplished is the performance of the mechanical work necessary for the extraction and hauling of coal or ore. The essential characteristics necessary in the power transmission used in underground mining to meet the severe conditions of that service are flexibility, reliability, economy of space and cost, ability to transmit power to long distances with small loss, and facility of extension and repair. And it has been successfully demonstrated after years of service that in these important characteristics, electric power is so much the superior of the others, that it has found general adoption for most of the important operations in mining service, including main shaft hoisting, slope hoisting, locomotive haulage, ventilation, pumping, coal cutting and drilling, preparation of coal in breaker, and lighting.

The transmission of any power for the various operations in underground mining opens up a very interesting field for the solution of questions involving the economical relationship between the loss in power and the investment in transmitting mediums, for the reason that the most economical centers of distribution for underground operation are not always accessible from above ground. For example, the mine shaft has been used as a passage through which to carry the transmitting medium down into the mine, and it therefore becomes the fixed center of distribution. In mines, therefore, with long gangways, and numerous pumps, locomotives, coal cutters, drillers, etc., in operation, the loss in pressure becomes an important consideration. In addition to this, it is preferable to avoid, as far as possible, running bulky power transmitting mediums along the gangways, on account of the limited space and the nature of the roof and walls, and also on account of their liability to mechanical injury. Therefore, in order to effect the much desired economical relationship between investment in transmitting medium and loss in power, and in order to insure certain other desirable conditions, it is the practice to drill "feeder bores," or small pipe lined holes, down into the mine at appropriate points between the mine shaft and the end of the gangways, through which the power is fed into the mine.

Among other interesting features in connection with a power transmission system in underground operations are, the sulphurous nature of the moisture and water of the mines, involving corrosion and decay of materials; the necessarily limited head room and working space in the mines; the rough character of the work; the variable nature of the walls and roofs of gangways and chambers; the frequent blasting operations, requiring adequate provision for the protection of the system from mechanical and chemical injury; and the frequent moving of pumps, etc., making flexibility of transmission an absolute necessity. It is to these peculiarly severe conditions that electric transmission seems especially applicable, as offering a comparatively easy means of overcoming their difficulties.

In following a brief description of some of the features of the electric wiring system of mines, it should be remembered that no two mines are alike in details, and methods that will apply in one case may not fit the peculiar conditions found in others. The purpose of this article is, therefore, to describe but briefly a few of the essential devices used in the wiring equipment of coal mines in general. A tabulated list of the cables, wires, and wiring devices that are suitable for lighting and motor service in mines would be somewhat as follows:

Feeder cables from power station to mine shaft, and to trolley wires in gangway.

Lead armored feeder cables to run down mine shaft and feeder bores; as well as into pump chambers where wires are exposed to injury.

Feeder wires from power station to coal breakers and other buildings above ground, and to surface and tunnel trolley systems.

Trolley wire for locomotive haulage, with suspensions, frogs, ears, etc.

Insulated and bare circuit wires for lighting, above and below ground.

Metal conduit to protect wiring from mechanical injury in coal breakers, washeries, tunnels, shafts, etc.

Flexible steel armored conductors for coal cutters, drillers, etc.

Reinforced duplex flexible conductors for portable lamps, etc.

Weatherproof keyless lamp sockets, portable lamp guards, glass and procelain insulators, knife switches, and porcelain receptacles for lamps on side walls where not exposed to mechanical injury.

In mines using alternating current supplied from a central station and fed to substations near the mine shafts, the only items which appear necessary to be added to the above list are the high potential feeder cables from central station to substation, which are sometimes bare, and sometimes insulated, depending, among other conditions, upon whether the transmission lines are, or are not, exposed to interference or public traffic.

Many of the electrically equipped mines of today use direct current of comparatively low voltage; *viz.*, 250 to 500 volts; but owing to the rapid extension of the mines, and the operation of extensive mining properties under a single progressive management, it is safe to predict that the alternating current will ultimately find general adoption in mining operations. This will be largely due to the fact that the economical transmission of direct current at standard voltages is limited to short distances and comparatively small loads by the cost of copper, while alternating current of economic voltages can be transmitted long distances at comparatively small cost for line construction, and the voltage easily and cheaply raised or lowered to suit conditions.

The coal mining department of the Delaware, Lackawanna & Western Railway Co. have a central station using Curtis steam turbines generating alternating current at 2300 volts, which is carried on overhead transmission lines to the substations situated at the various mines. The substations contain rotary converters for converting the alternating current to direct current for locomotive haulage, and step-down static transformers for feeding various alternating current motors down in the mine. Fig. 1 shows the front view of the central station switchboard, manufactured by the General Electric Co. A brief description of this switchboard may be interesting.

When installed in 1905, the switchboard consisted of seven blue Vermont marble panels, the first panel on the left controlling the two engine-driven exciters; the next three controlling the three turbine-driven generators; and the fifth, of 1500 kw. capacity, controlling the feeders for the motors in the water hoisting plant. Panels 6 and 7, of 500 kw. capacity each, are feeder panels, controlling the feeders to the substations. A recording wattmeter is placed on the back of each feeder panel, and triple conductor lead armored cables are run from these, under the floor and up the side walls of the station, connecting with the bare transmission lines leading to the substation.

Each of the substations contains a 200 kw. General Electric six-phase rotary converter for direct current light and power service (Fig. 2), and also three 75 kw. step-down transformers for alternating current motor service, in and around the mines. The switchboard consists of two panels; *viz.*, a 2300 volt A.C. panel, fitted with the usual fuses, meters and oil switch; and a D.C. panel, provided with a single pole circuit breaker, ammeter, field rheostat, and single pole single throw switch. The switch controls only the positive lead of the rotary, the negative side being grounded to the rails of the haulage system.

When the mine shaft is dry, and no trouble is likely to occur from falling ice or coal, the power feeder leading into the mines consists of rubber covered wire supported on glass insulators fastened to the buntons. However, this condition is so seldom found that lead covered cables placed in iron pipes are generally used. This method has given good results, even in very wet shafts.

The following method of supporting feeder cables running down the shaft is suggested and used by the electrical engineer of the Delaware, Lackawanna & Western coal department, and has given entire satisfaction. A number of rubber pump valves about 6 in. in diameter are strung on a supporting rod to provide proper insulation, and the rod is then secured in place by strap irons fastened to the buntons, or some other convenient place. The lead of the lead armored cable is taken off for a distance of about 4 ft., and the bare cable is given one or more turns about the support just described, and then clamped to itself. The lead armor is stripped off to prevent the weight of the cable from crushing the insulation surrounding the wire and causing a short circuit between the conductor and the lead covering. Wooden bushings soaked in paraffin and then shellaced are fastened in the ends of the pipe to pre-

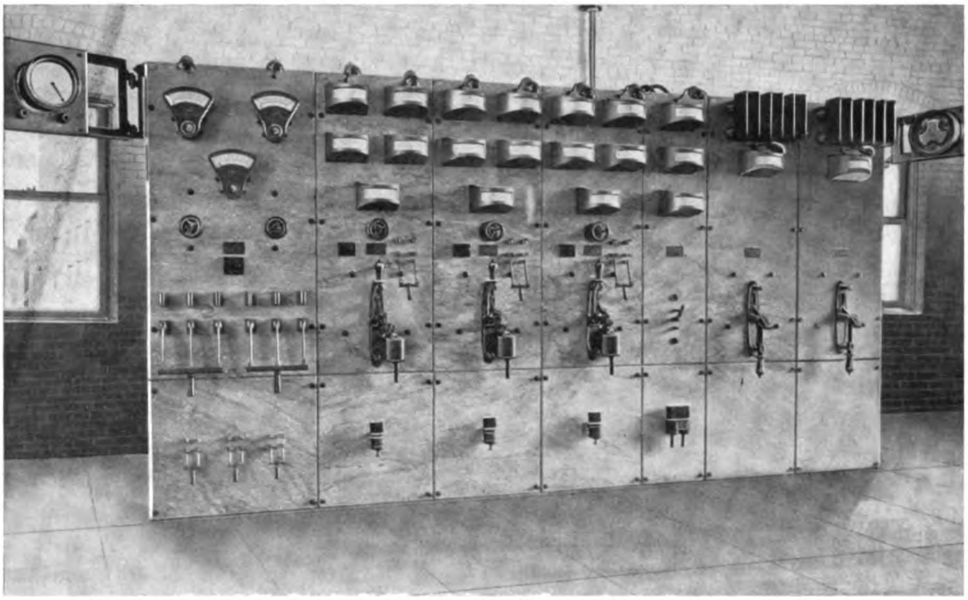


Fig. 1. Central Station Switchboard, Coal Mining Dept., Delaware, Lackawana & Western Railroad

vent the cable from being damaged or short circuited at this point. In cases where the depth of the shaft would produce excessive weight on the top support just described, the following arrangement is resorted to:

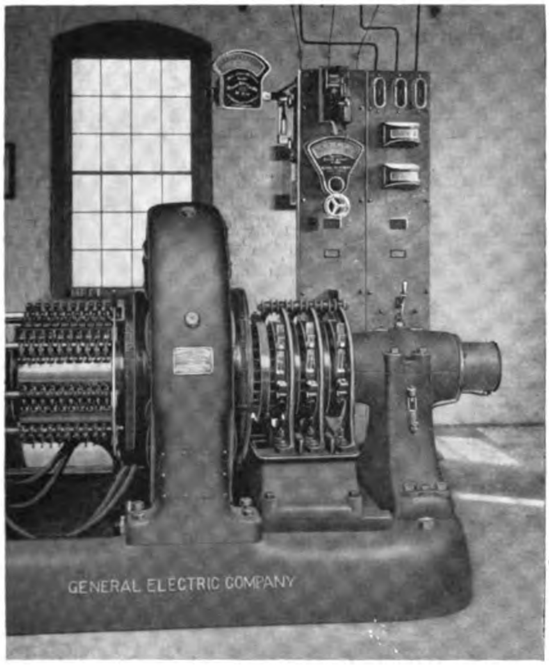


Fig. 2. Interior of Substation, Coal Mining Dept., Delaware Lackawana & Western Railroad

At the foot of the shaft, where the cable emerges from the iron pipe, through which it is carried down the shaft, a clamp is fastened to the cable and to the pipe; the cable, thus secured at the bottom of the shaft, is dropped down in the pipe to a certain extent, causing the cable to coil, or assume a wave like position, whereby a frictional support is secured against the sides of the pipe. This method of suspending feeder cables in shafts would also apply to those running down "feeder bores," the upper end of the cable, in some mines, being secured to a suitable wooden support. The feeders are looped into distributing bus-bars at each vein or gangway, and these feed the trolley wire, pumps, motors, lighting circuits, etc.

(*To be continued.*)

MOTOR DRIVEN DRAINAGE PUMP

A somewhat novel and interesting portable electric pump has been built by Yeomans Brothers of Chicago, for the Omaha Electric Light & Power Co., and is used by the latter for pumping out the manholes of their conduit systems. Rear and side views of the outfit are shown in Figs. 1 and 2.

The centrifugal pump is mounted on a bracket which forms one end of a long cast iron bed-plate designed to carry the motor and the inboard bearings of the pump.

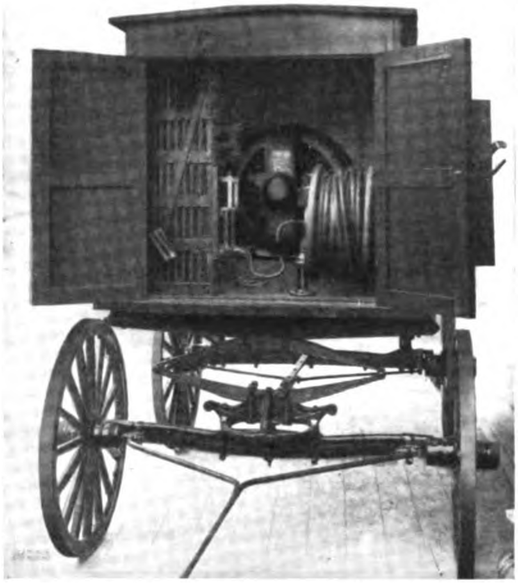


Fig. 1. Rear View of Portable Motor Driven Drainage Pump

The power is supplied by a direct current 10 h.p., 835 r.p.m., 500 volt General Electric motor. The pump has a capacity of from 450 to 500 gallons per minute against a maximum head of about 25 feet.

Below the flexible coupling which connects the motor shaft to the pump shaft will be seen a small secondary pump driven by a belt from the main shaft. The function of this secondary pump is to prime the casing of the main pump.

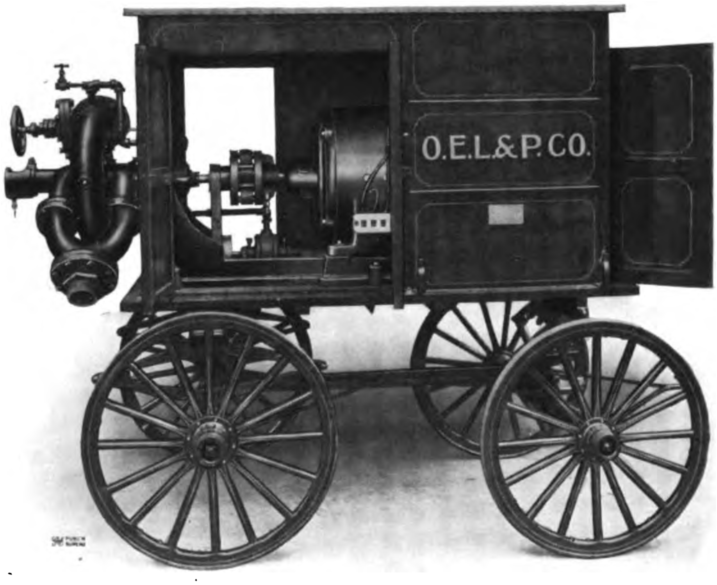


Fig. 2. Side View of Portable Motor Driven Pump

When it is desired to put the apparatus in operation, the main discharge valve is closed and the motor being started up, the small centrifugal vacuum pump exhausts the air from the casing of the main pump, causing sufficient water to rise out of the sump or manhole to prime the casing of the latter. As soon as this is accomplished the discharge valve of the main pump may be opened, and the speed regulated to suit existing conditions of head and flow.

The priming pump is fitted with a fast and loose pulley so that as soon as the main pump has begun to deliver water, its belt can be shifted onto the loose pulley, thereby permitting the smaller pump to come to rest.

Speed control is accomplished by means of a regulating resistance box which is shown in Fig. 2 on the left-hand side of the wagon. On the right is a reel carrying a flexible a ready access obtained to all parts of the connecting cord 200 ft. long, one terminal of which is permanently connected through the axle to the starting box, the other to be connected to a convenient source of electricity, which is to be found either in a manhole, in case of making connection with the underground system, or at a feeder or main junction box, in the case of a pole line.

The wagon-top is made removable so that in case of necessity it can be taken off, and apparatus.

Provision is made for carrying the suction hose on the side of the wagon body, in a manner very similar to that employed in connection with fire engines.

With the rapidly increasing use of underground distribution systems, it is evident that an apparatus of this kind will prove of the utmost utility, not only in removing the ordinary seepage and condensation which at times gathers in manholes and ducts, but it will prove especially effective and valuable in case of emergency or accident, such as frequently happens in underground systems when a conflagration or explosion occurs in their immediate vicinity.

F. M. K.

LUMINOUS ARC HEADLIGHT

By G. N. Chamberlin

An article in the October number of the General Electric Review described a new application of the direct current luminous arc; *viz.*, its use for street car headlights. This type of headlight is meeting with general favor among street car operating companies, and in every case where samples have been furnished, either additional orders have been received or assurance given that the luminous arc headlight will be specified if additional equipment is required. One company advises us that after trying two samples for a period of three months, they feel that they can no longer afford to use about 100 enclosed carbon headlights of a well-known make. Without taking into consideration the increased volume of light, and the fact that the arc is focusing, the decrease in operating expenses obtained by this particular company by the use of the luminous arc headlights, warrants the inquiry for prices for replacing all carbon headlights in use.

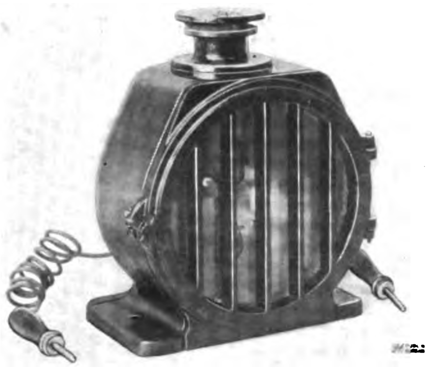


Fig. 1. Luminous Arc Headlight for Mining Locomotives Front View.

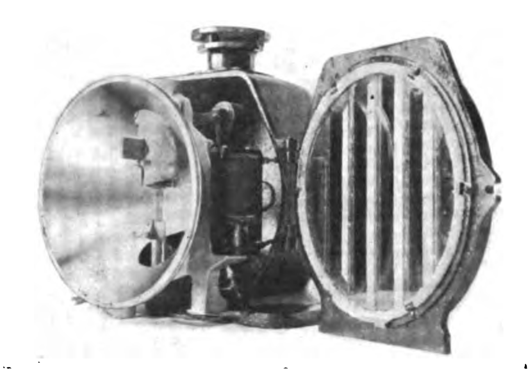


Fig. 2. Headlight Open for Inspection

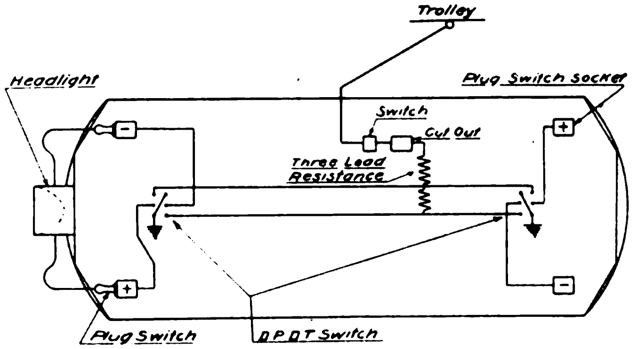


Fig. 3

Figs. 1 and 2, illustrate a type of headlight for mining locomotives which, while designed for this particular service, is available for use wherever a heavy cast frame of small dimensions is required. The internal mechanism and electrodes (upper copper and lower composition) are identical with those used for street car service, a full description of which will be found in the article referred to above.

The casing is of cast iron, including heavy cast iron bars for protecting the glass door. The casing complete weighs about 55 lbs. and is arranged for bolting to a horizontal surface; it is evident that this type of frame should be used where permanent installation may be made, and where increased weight is not objectionable.

For electric switching, mining and general railroad locomotives, and for stationary lighting where an efficient broad beamed semi-projector method of illumination is required, this type of luminous headlight is recommended. The headlight is furnished with two leads, plugs and receptacles, and is adapted for connection on direct current circuits of from 200 to 600 volts. A suitable resistance being furnished for any special voltage.

Wiring diagrams for different connections of the headlight are shown in Figs. 4, 5 and 6.

Without repeating the detailed information given in the article in the October REVIEW entitled "Magnetite Headlight," the advantages of the luminous headlight as compared with the enclosed carbon headlight are as follows:

1. The higher efficiency of the magnetite arc, giving quantity and quality of illumination.
2. Arc maintained at focus of reflector, insuring permanent direction of rays.
3. No enclosing globes used, thus eliminating greatest expense of enclosed headlight maintenance.
4. Long life of electrodes–2000 to 3000 hours for upper, 50 to 75 hours for lower showing a further reduction in operating expense.
5. Available means of quickly and effectually dimming the light—a modern method as compared with the use of screens hung in front of headlight door.

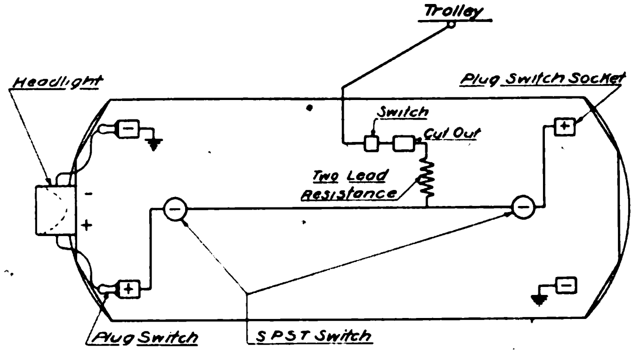


Fig. 4

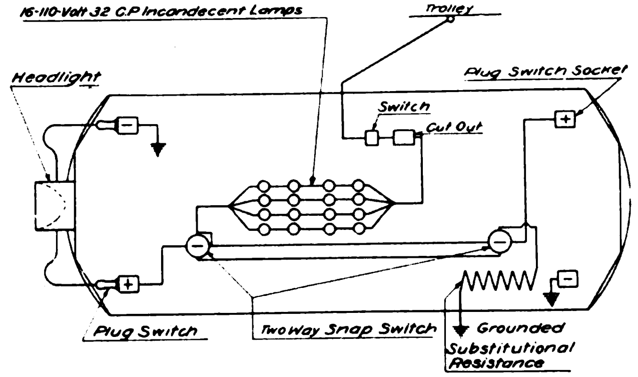


Fig. 5

THE "INVINCIBLE" RENOVATOR

By Thomas Raddin

There has been placed on the market very recently a unique renovating device known as the "Invincible" Electric Renovator, which is manufactured by the Electric Renovator Mfg. Co., of Pittsburg, Pa.

This machine fills a long felt want in the cleaning field for house, church and hall renovating, and affords a most convenient method of disinfection.

The machine is operated on the suction principle, and is driven by a small direct connected motor. As may be noted by referring to the illustration, the front part of the machine is equipped with an aluminum casing, and inside of this is located a brush which is driven by a small belt connection from the fan shaft. This brush may be adjusted to the texture of the carpet to be renovated, and will therefore cause no undue wear on the nap of the carpet or rug. The inlet is 12 inches long by 13 inches wide at the point of contact with the carpet, and the suction is of sufficient strength and volume to remove the dust, grit and fluff from beneath the latter.

It is interesting to follow the course of the dust after it leaves the floor. It travels around the brush, past the removable trash drawer (designed to catch matches, string and other articles which might damage the fans) through the netting covering the inlet to the fans, and into the fan casing. This casing is divided into two stages by an aluminum diaphragm. The dust traverses these two stages and is driven upwards into the cylindrical dust collector, shown at the right of the machine in Fig. 1

The construction of this dust collector is worthy of brief mention. In consists of the finest woven muslin cloth, which catches all of the dust coming from the renovated surface, but allows the air to pass through and out into the room. The muslin collector is surrounded by a fine wire mesh.

The accumulated dust may be removed by lifting the collector by the handle at the top, having first detached the four wing nuts shown on the under side of the collector; while the bottom part, which is provided with lugs, may be unscrewed from its connection. By tapping the collector lightly the dust is discharged, and the collector is again ready for service.

The services of this machine are not limited to renovating carpets. The connection between the brush casing and the fan casing is provided with a two-way cock which enables the floor inlet to be closed, and the air inlet transferred to the hose connection. A large number of tools for various uses are furnished with each machine, enabling the operator to clean walls, ceilings, mouldings, pictures, tapestries, and so on, and also to reach under radiators and other inaccessible places. By transferring the hose from the inlet to the discharge, and using an atomizer tool, a room may be disinfected in a most thorough manner. This machine affords an excellent means for renovating pillows and feather beds; first, by going over the outer surface with the suction tool, and second, by transferring the hose to the discharge outlet and "blowing up" the pillows, so to speak, with a special tool furnished with the machine.

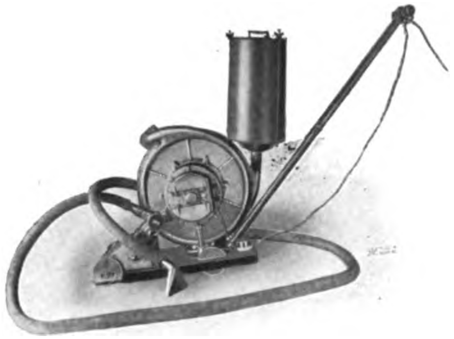


Fig. 1. "Invincible" Renovator

In this manner the pillow is thoroughly cleaned, and the feathers are agitated and aerated.

The machine is built of aluminum with the exception of the motor, and is so light that a woman can operate it with ease. It is mounted on two rubber tired wheels, and the amount of surface that comes in contact with the carpet is very small.

The motors are of the General Electric Company's semi-standard type, designed for this particular machine, and can be furnished for 110 or 220 volts, direct current or single-phase alternating current. The starting features of the machine are very simple, it being merely necessary to turn the small snap switch located on the motor, thus completing the circuit, and the motor will drive the fans up to full speed.

The machine commends itself to a wide range of usage, and the owner will frequently find new and unique methods of applying either the suction or the pressure connections.

It is interesting to note that several machines have been installed in up-to-date garages for cleaning and renovating the automobiles as they come in from the road. For theatre renovating it has proven indispensable, and this fact is evidenced by the large number of machines installed in the various theatres throughout the East. The machine can also be used to good advantage for cleaning horses, and should appeal particularly to owners of large livery and boarding stables,

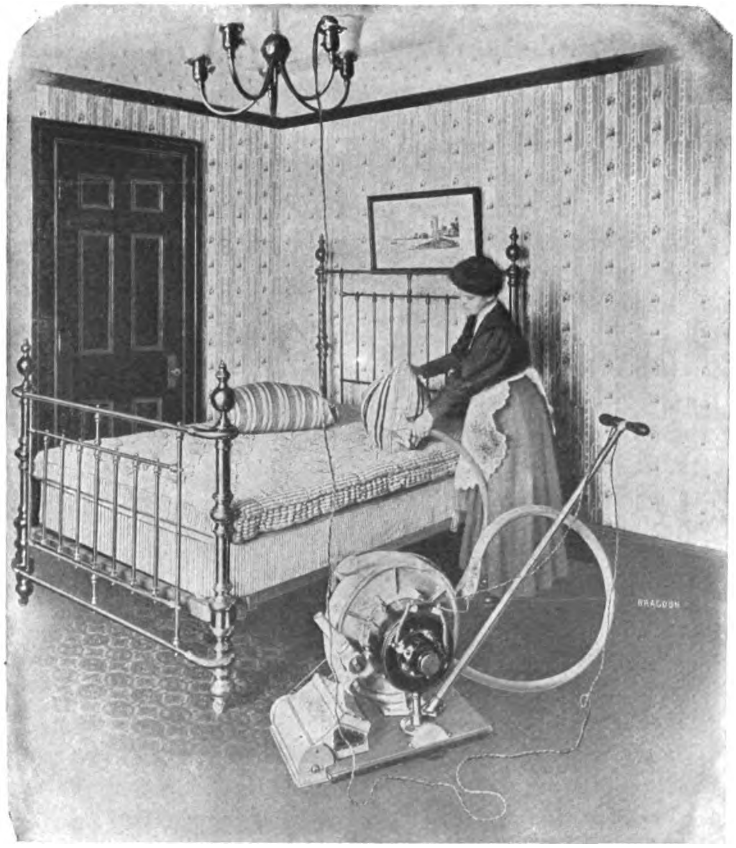


Fig. 2. Renovator Aerating Bedding

as it can be moved from one part of the stable to another, providing a flexible and convenient method of cleaning the horses.

The average person does not fully appreciate the dangers arising from improper cleaning and disinfecting in the home and office buildings, but this machine affords him a cheap, portable and efficient method of keeping carpets, rugs, chairs, etc., in a thoroughly sanitary condition.

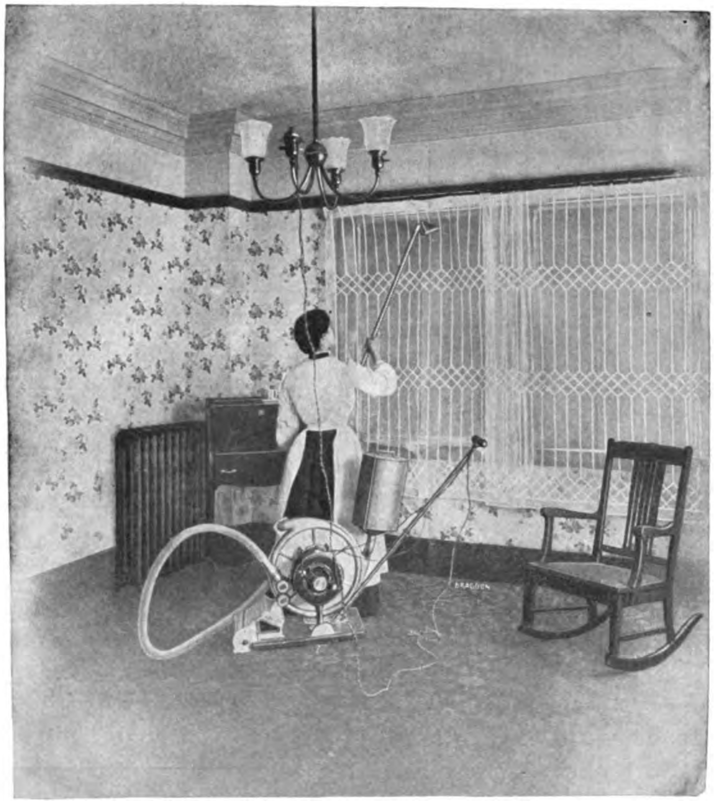


Fig. 3. Renovator Removing Dust from Window Curtains

A MOTOR DRIVEN LAUNDRY

By L. E. Smith
Small Motor Department General Electric Co.

In discussing the advantages of the electric drive with customers they frequently reply, " Yes, electric power is very convenient and has many advantages, but I cannot afford to pay for the increased charges entailed by its use. I require steam, anyway, so that the use of the steam engine for power adds little to my expenditures."

The numerous benefits which result to a customer from installing electric drive do not appeal to such persons, unless it can be shown, in addition, that the electric motor will reduce, at least slightly, the monthly cost of power. General statements regarding possible savings have little or no convincing effect. If the order of such a prospective purchaser is to be secured, he must be shown by actual figures that the purchase and use of electric motors means a saving of so many dollars and cents per month. A careful comparison of the customer's present power cost when using his steam engine, with a close estimate of the power cost when employing electric motors, will frequently astonish the prospective customer, and discredit his argument that electric power is more expensive, notwithstanding its added conveniences.

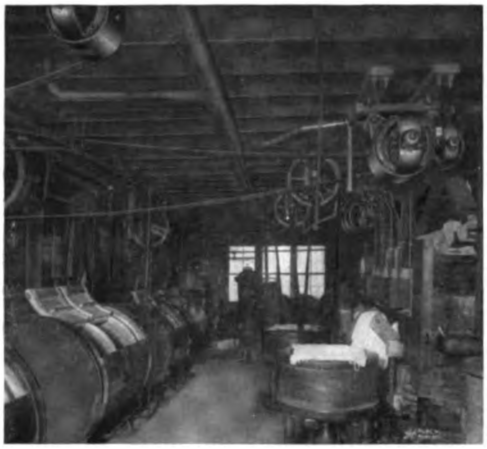


Fig. 1. General Electric Motor Driving Washing Machine

Possibly the proprietors of steam laundries are more difficult to convince than others that the use of electric motors and central station service will be less expensive than older means of power supply, because they actually require a steam boiler in their work all the year, and argue that the added cost of operating a steam engine under these conditions is almost negligible.

Therefore, in the following tabulation it may be of interest to note the relative costs of the two methods, based on actual figures taken from the records of an electrically operated laundry that has been in satisfactory operation for the last year.

WITH STEAM ENGINE

Item	Dollars per Month
Coal	$60.00
Labor	62.50
Water	16.00

WITH ELECTRIC MOTORS

Item	Dollars per Month
Coal	$25.00
Labor	12.50
Water	11.00
Electric current . .	45.00

Steam engine, Total	$138.50
Electric motors, Total.....	93.50

Saving over steam drive, $45.00 per month, or $540.00 per annum, which is equal to one year's interest at 36 per cent. on the investment required. In addition to covering interest on the investment at 6 per cent., the saving will return the entire cost of the change from steam to electric drive in three years and four months, no allowance being made for the old engine.

It will be noted in the above tabulation that no comparison has been drawn between the cost of maintenance of the two systems. As an actual fact, this amounts to practically nothing in the case of electric drive, while with the steam engine repairs are frequent and expensive, due not only to their actual cost, but also to the value of the time lost during repairs, as the whole plant goes out of service when there is any trouble. In addi-

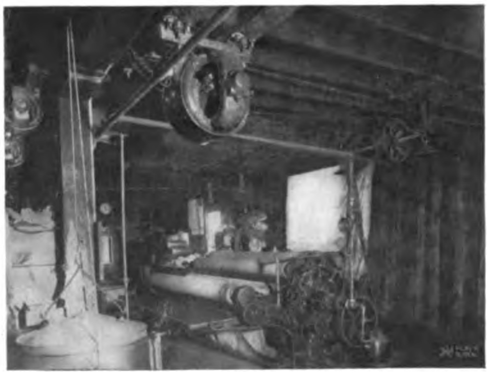


Fig. 2. General Electric Motor Driving Laundry Mangle

tion to all this, the cost of oil is greatly reduced, as well as the cost of belts and the maintenance expense of shafting.

Under the same conditions, a laundry in another part of the country might show a much greater saving, due to the fact that it was located in the heart of the coal district, where soft coal can be purchased at the rate of from $1.50 to $1.75 a ton; whereas in other parts of the country, the cost per ton runs up to two or three times this amount.

The rate of 5½ cents per kilowatt hour compares favorably with the rates of many other central stations, and a water rate of 9.3 cents per thousand gallons is a fair average.

The laundry herein referred to has in service a total of 16 General Electric CQ motors, which are distributed as follows:

One	5	h.p. motor	operating	carpet cleaner,
Two	5	h.p. motors	"	washing machines,
One	2½	h.p. motor	"	collar ironer,
One	2½	h.p. "	"	mangle,
Two	2	h.p. motors	"	extractors,
One	½	h.p. motor	"	exhaust fan,
One	½	h.p. "	"	bosom ironer,
One	½	h.p. "	"	starcher,
One	½	h.p. "	"	blower,
One	½	h.p. "	"	body ironer,
One	¼	h.p. "	"	collar shaper,
One	¼	h.p. "	"	collar starcher.

The two accompanying illustrations show the typical methods used in making the installation—suspending the motors from the ceiling and employing only light countershafting, and as little of that as possible. The chief advantages of an individual drive are obtained by doing away with long series of line shafting and belting, as in this way the machines are entirely independent, and may be so operated as to best meet daily conditions of business.

If a prospective customer can be shown as favorable a proposition as the above, based on his present power cost and an estimate of electric power, he can no longer say, "Does it pay?" but, "Can I afford to do without the electric motor?"

A MODEL SMALL ISOLATED PLANT

By Edw. E. Peasley

Dreamy, picturesque Vineyard Haven!—probably the last place one would naturally expect to find an installation of man's latest and greatest development in the steam engineering line—the Curtis steam turbine.

This town, tucked away on Martha's Vineyard, a half hour's sail from the southern coast of Massachusetts, is the Mecca of pleasure seeking vacationists from June to October, and its quaint old houses and winding streets give no indication that enterprise would locate here, or if established, would install a plant which lends excuse to the caption of this article.

Powerhouse of Luxemoor Co., Vineyard Haven, Mass.

The plant mentioned is that of the Luxemoor Company, manufacturers of fancy leather, and consists of a 25 kw., 125 volt Curtis turbine-generator, furnishing current for power and lighting in the factory. The treatment of the entire installation has been in accord with the best modern engineering practice, and shows the result of careful planning intelligently carried out to the smallest details.

The power house is located about twenty-five feet from the factory and is a one-story building built of natural field stone laid in cement. Its appearance is pleasing to the eye, and its location, under the brow of a slight hill, is such that the discharge of the exhaust is not prominent from the main street, which contains many beautiful summer residences in the immediate vicinity. Unlike the exhaust from reciprocating engines, that from the Curtis turbine is noiseless, thus eliminating another objectionable feature.

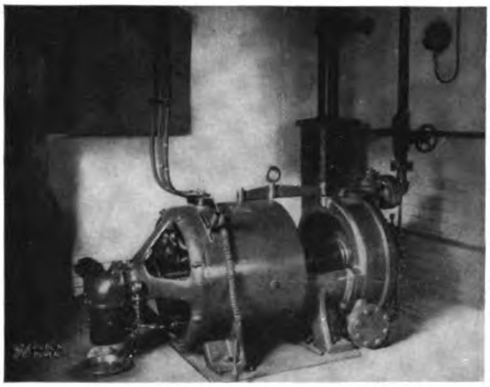


Fig. 2. 25 Kw. Curtis Turbine-Generator Installed in Luxemoor Company's Power House

The power house (Fig. 1) consists of two rooms separated by a heavy fire wall, one room containing the 50 h.p. tubular boiler supplying steam at 125 lbs. pressure; the other room the turbine set and a two panel black slate switchboard, consisting of a generator panel and a four-circuit feeder panel (as shown in Figs. 2 and 3). The floor in both rooms is of cement, finished smooth. The generator room was made of size sufficient to accomodate another 25 kw. turbine unit, although hardly large enough to take in a reciprocating set of like capacity.

Power is delivered to a short line shaft in the factory by a 20 h.p. slow speed motor of the CLB type; and from this shaft are driven the five or six machines used in their processes.

The owners are loud in their praise of the small turbine, stating that since the apparatus was installed in 1906, it has never been out of commission, and that they have not expended a cent for repairs of any kind. They are further convinced that their fuel cost is much lower than would be the case if a reciprocating engine were used, due to the well maintained efficiency of the turbine. The cost of attendance is practically negligible, as their fireman acts as engineer and has considerable time for other duties outside the power house, the turbine requiring almost no attention.

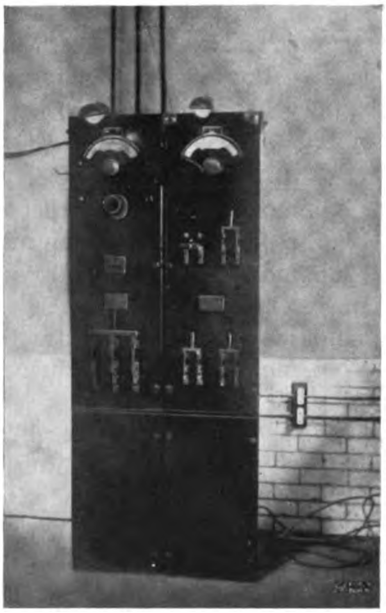


Fig. 3. Switchboard of Power House

NOTES

EASTERN NEW YORK SOCIETY OF CHEMISTS

The fact that interests other than electrical are being fostered and developed in Schenectady through social organization, is shown by the formation of an Eastern New York Society of Chemists, in the Laboratory at Union College, December 16th.

The meeting was addressed by Marston T. Bogart, Ph. D., of Columbia University, President of the American Chemical Society and of world-wide reputation for researches in the field of organic chemistry.

The subject of Dr. Bogart's remarks, "Stereo Chemistry," was handled in a masterly and most interesting manner, and each person present was enabled to follow the speaker closely by the aid of the diagrams and excellent models shown.

Following the address, organization was effected by the election of officers, as follows:

President, Dr. W. R. Whitney, of the General Electric Research Laboratory; Vice-President, Prof. Edward Ellery, of Union College; Secretary, F. C. Zapf, Research Laboratory of the General Electric Company; Treasurer, L. M. Willey, Research Laboratory of the General Electric Company.

The officers, with the three following gentlemen, were elected as an Executive Committee, to arrange for further meetings and programs for the Society: Dr. Wm. P. Mason, Rensselaer Polytechnic Institute, Troy; Mr. John Hurley, Little Falls; Dr. Edward J. Wheeler, State Department of Agriculture, Albany.

The Society embraces a territory lying within a radius of sixty miles of Schenectady, and many noted workers in the field of chemistry are included within this boundary. It is planned to hold meetings monthly during all but the summer months, and it is expected that some of the ablest authorities on chemical science in the country will be heard here under the auspices of this organization.

Application has been made to the American Chemical Society for a charter as a Local Section, and it is expected that action will be taken on this matter at the Chicago meeting, December 31st to January 4th.

PITTSFIELD SECTION A.I.E.E.

Season of 1907-1908

The Pittsfield Section of the American Institute of Electrical Engineers has started its season most auspiciously, and has an interesting series of meetings planned for the coming year. The Section has adopted the plan of admitting "local" and "student" members on payment of one dollar and fifty cents and one dollar, respectively. As a result of a careful canvass by an active committee, the membership has been increased by rapid strides from about twenty-six members on last year's roll to two hundred and two members, between the dates of November 2nd and December 6th.

In addition to the meetings of the Executive Committee, three regular meetings have been held.

The first meeting of the Section, which was held on November 2nd in the attractive parlors at the Wendell Hotel, was addressed by Mr. D. B. Rushmore, of the Power and Mining Dept. of the General Electric Co., Schenectady, who spoke in a very interesting manner on the organization and work of the Institute, and the work of the Schenectady Section. Mr. Rushmore's remarks were especially appropriate for the opening meeting, and greatly assisted the officers of the Pittsfield Section in stirring up an active interest in the work. The Secretary gave a list of the speakers who had consented to present papers before the Section. Forty-one new members were enrolled by the Membership Committee at the close of the meeting, and an informal reception and smoker added to the enjoyment of the occasion.

The second meeting of the Section was held on November 14th and, on account of the increase in membership, the meeting had to be held in the large dining room of the Wendell Hotel. One hundred and ten members were present, who listened attentively to a very interesting lecture by Mr. H. H. Barnes, Jr., on the "Curtis Steam Turbine." Mr. Barnes gave a very clear and comprehensive description of the construction and operation of the turbine, and brought out a large number of special features of the Curtis machine, especially in regard to matters of economy in floor space, steam comsumption, etc. The lecture was illustrated with lantern slides, and a feature of the evening was a number of humorous slides which provided amusement for both the speaker and the audience.

An audience of one hundred members greeted Mr. E. B. Merriam at the third meeting, held on the evening of December 6th. Mr. Merriam selected as his subject "Some Notes on High Power Testing," and described a large number of developments in the design of apparatus for controlling electrical equipments of large capacities. The talk was illustrated with a large number of lantern slides, showing the construction of the later styles of circuit breakers, oil switches, fuses, relays, etc., and the same devices under tests. Oscillograph records were also shown and a brief description was given of the construction and operation of the oscillograph.

Following the lecture, there was a brief discussion of the points brought out during the evening.

It is the aim of the Committee to have the majority of the meetings of a popular nature, and as informal as possible. Special features are to be introduced from time to time to provide some amusement, and to break away from the regular routine.

The Executive Committee for the Pittsfield Section for the year is: Mr. Joseph Insull, Chairman; Mr. Henry L. Smith, Secretary; and Mr. W. A. Whittlesey.

* * * *

The new gas-electric car, described on page 101 of this issue of the Review, received official test on January 15th, the run being made from Schenectady to Delanson, thence to Albany, Troy and back to Schenectady. This route was eminently suited for testing the car on curves and grades; and its performance was even more satisfactory than had been anticipated. A party of officials and engineers from the Delaware & Hudson Railroad, the American Locomotive Company and the General Electric Company, attended the trial trip.

* * * *

The following Bulletins have been issued by the Publication Bureau of the General Electric Company, since publishing the previous list, to be found in the November number of the Review.

4540	Parts of GE–90–A and B Railway Motors.
4541	Parts of Edgewise Parallel Rod 220 volt, D.C. Multiple Enclosed Arc Lamps, Forms 7 and 6.
4542	Concentric and Inverted Diffusers.
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4546	Electrification of the West Shore Railroad.
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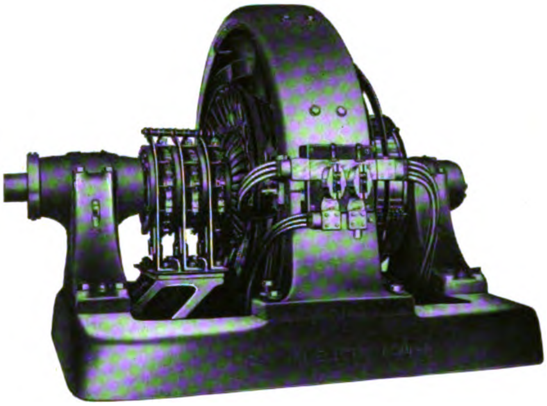

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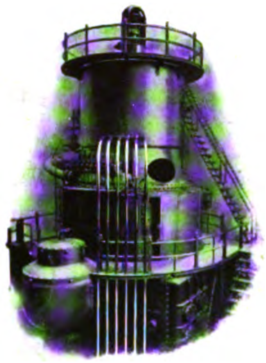

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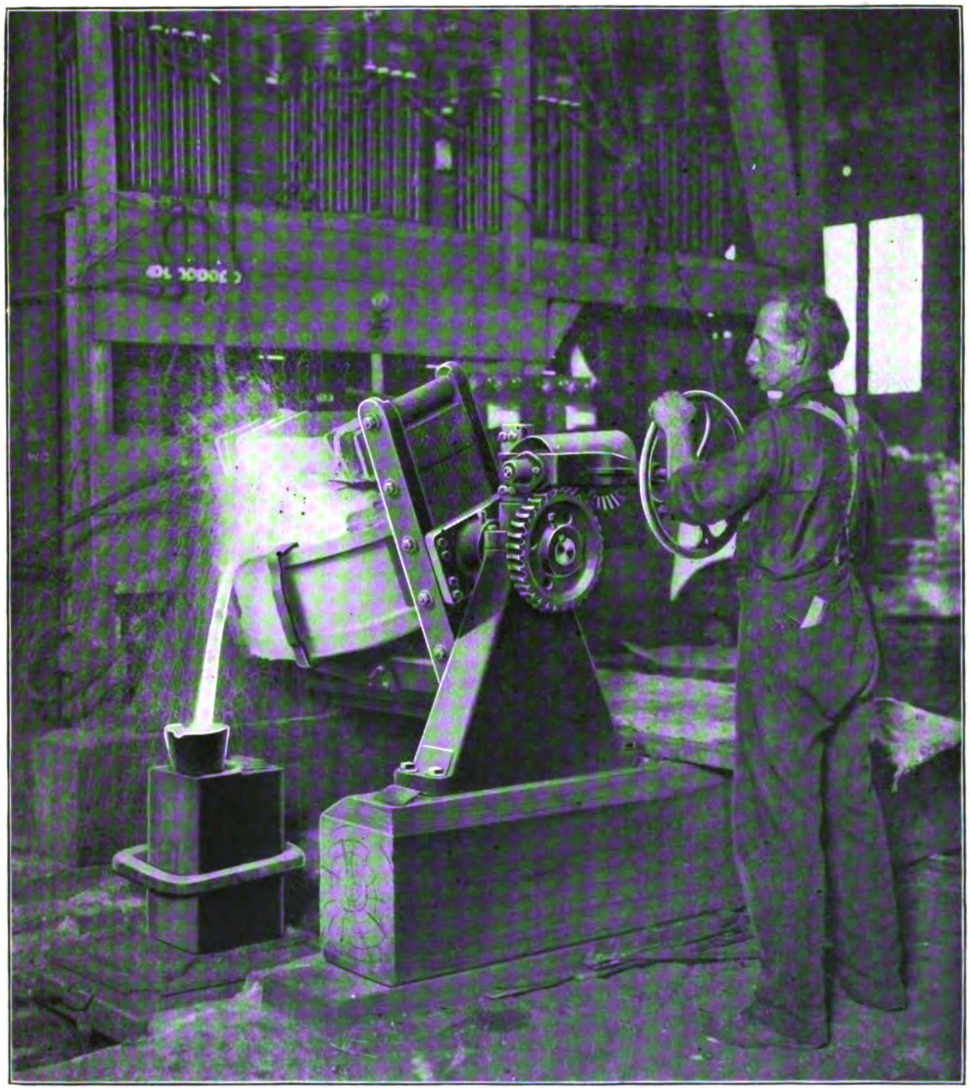

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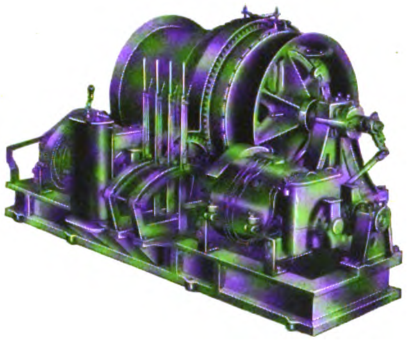

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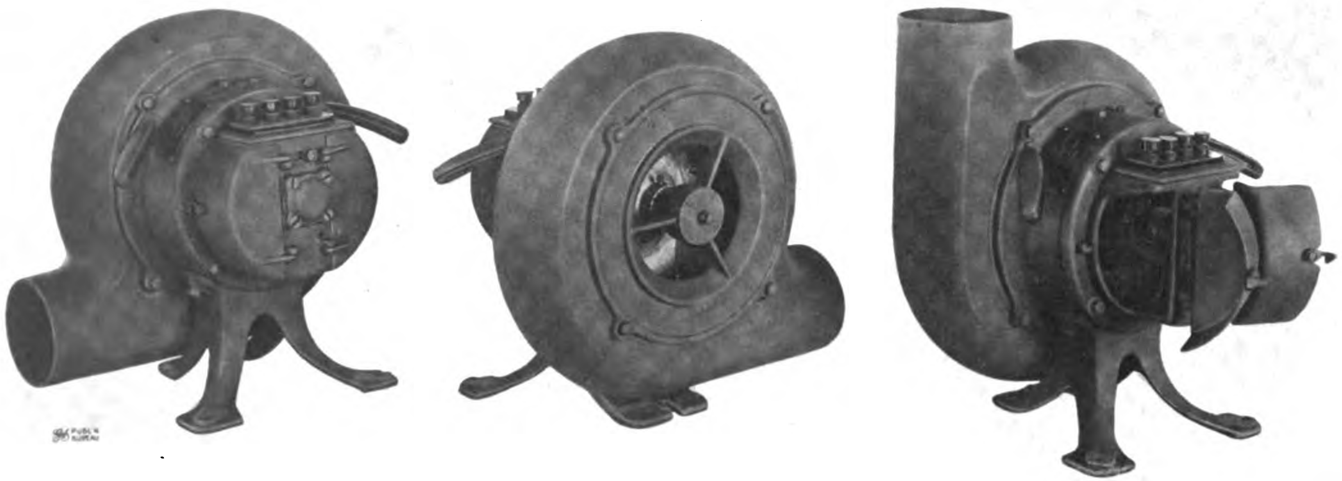

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(See page 194)

Vol. X, No. 4 SCHENECTADY March, 1908

GENERAL ELECTRIC REVIEW

CENTRAL STATION REDEVELOPMENT OF WATER POWER*

By Robert E. Horton,
Hydraulic Engineer

The object of this paper is to present a resumé of the advantages that may result from the substitution of central hydro-electric power stations with short transmission lines to the mills, in place of the present systems of power development and distribution at many existing water power centers.

Advantages of Redevelopment

As compared with an entirely new power undertaking, the redevelopment of existing water powers presents certain advantages.

(1) In original development a market must, as a rule, be created either by displacing existing motive power—usually costly steam plants—or else by creating or attracting new industries. Furthermore, the power must usually be transmitted several miles, and right of way and franchises obtained, often under conditions of competition.

(2) In redevelopment, the power is at the site where it is to be used; a part will be taken by established and operating concerns that have hitherto used the same power, and these will be the best customers for the additional power created. Their existing water wheel plants will be displaced, it is true, but where these are old, leaky and inefficient, as is very commonly the case, the riparian owner will be relieved of the cost of replacement and repairs, and will often gain valuable land and room, formerly occupied by canals, flumes and penstocks.

In order to induce a riparian owner to join in a scheme for redevelopment, he must be approached with arguments showing the advantages of the scheme, compared with a continuation of the existing system of development. This may be done in part by outlining the disadvantages of the methods in use.

(3) In general, redevelopment will result in a large gain in the power available. This will be accomplished through an increase in the average head, efficiency of turbines, reduction of waste and leakage, and better utilization of pondage. These matters will be discussed in detail as we proceed.

(4) With redevelopment, the necessity of crowding the mills into a narrow compass accessible to the hydraulic canals will be removed, and manufacturing districts will be afforded a chance to expand.

Early Methods of Utilizing Water Power

The system of power distribution in use in many of the older water power cities consists of a series of head races, or hydraulic canals as they are called, carrying the water to the mills where it is to be used. At the time the earlier developments were made, overshot and breast wheels were in vogue, and to accommodate these, the fall, if it exceeded twenty or thirty feet, was divided into two or more levels. A large water power in Northern New York wasted, until recently, two-thirds of the available fall, and gave as a reason, that it was impracticable to operate a saw mill on a head of more than 16 feet.

The sub-division of the head into several levels also increased the opportunities for dividing the power into small units, and enabled the area supplied with power to be extended. As a rule, the tail races of mills taking water from one level discharge into the next level below.

The distribution and return systems of canals often become very complex, as head canals occupy valuable space, and tail races sometimes have to be excavated or tunnelled

---

* Lecture delivered before the Schenectady Section A. I. E. E.

TABLE NO. I

Examples of the Hydraulic Canal System of Water Power Development

Compiled by Robert E. Horton, Hydraulic Engineer

River	Location	Drainage Area Sq. M.	Total Fall Ordinarily Available		Estimated Permanent h.p. available	Present Development					
			Feet	Air Line Distance		Hydraulic Canals No.	Hydraulic Canals Total Length Feet	No of Levels	Number of Mills	Heads under which Water is used	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	
Merrimac	Lawrence, Mass.	4625	28	5700	11000	2	7700	1	About 22	20 to 28	
Merrimac	Lowell, Mass.	4083	33	7000	11845	10	26200	2	" 10	14, 19	
Merrimac	Manchester, N. H.	2839	51	——	12000	3	12600	2	" 13	21, 30	
Connecticut	Holyoke, Mass.	8000	61	3250	14000	3	18500	3	" 50	36+12, 20+26	
Mohawk	Cohoes, N. Y.	3450	104	3600	9450	9	17500	5	" 30	18+25+22.5+19 +19	
Mohawk	Little Falls, N. Y.	1306	30	1000	1500	4	2400	2-3	"	8+18	State dam and Middle dam
Raquette	Potsdam, N. Y.	1000	10	Small	500	4	Small	1	" 9	10	
Saranac	Plattsburg, N. Y.	630	15	at dam	300	2	Small	1	" 6	4, 11, 10	
Oswegatchie	Ogdensburg, N. Y.	1609	8-12	Small	600	1	About 2500	1	" 16	8 to 12	
Black	Watertown, N. Y.	1900	70	4500	5600	4	——	1	" 7	10 to 17	Upper Fall Sewall Island
						3	——	1	" 8	11 to 18	Lower Falls Sewall Island
						4	——	1	" 10	8 to 20, 25	Upper level Beebe Island
						4	——	1	" 6	10 to 12, 15, 18	Lower level Beebe Island
Black	Black River, N. Y.	1880	16	500	1200	4	Small	1	" 9	8, 10, 11, 13 to 15	
Black	Carthage, N. Y.	1850	55	4750	3800	3	Small	1	" 3	11 to 13	Tannery dam
						2	600	1	" 14	6 1/2 to 9 1/2, 17	State dam
						1	Small	1	" 2	9, 18	Lower dam
Seneca	Baldwinsville, N. Y.	3120	11	2000±	500	3	3000	1	" 10	8 to 10	
Oswego	Oswego, N. Y.	5000	20	Short	2500	2	7000	1	" 15	16 to 20	Oswego and Varick Canals
Grand	Grand Rapids, Mich.	4900	14	2000±	2100	2	6300	1	" 12	8 to 14	
Hudson	Troy, N. Y.	8000	7-10	Small	1200	2	1200	1	" 8	7	

TABLE NO. 2

Examples of Cascade Development of Water Power

Stream	Location	Fall in Feet	Air Line Distance Miles	Drainage Area Sq.Miles	Storage Millions of Cu. Ft.	Estimated Permanent H.P. Available	Present Development		
							Number of Dams	Number of Mills	Fall now Utilized, Feet
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Rondout Creek	Napanoch, N. Y.	About 150	1.0	95	Honk Lake	300	7	9	125±
N.Chuctenunda Creek	Amsterdam, N. Y.	About 360	2.1	33	Ponds	100	Several	Many	——
Poestenkill	Troy, N. Y.	200	0.4	95	Ida Lake	300	4	12	120±
Lake George Outlet	Ticonderoga, N. Y.	About 225	1.25	234	45 Sq. M.	3000	3 or 4	10 or 15	140-160
Moodus Creek	E. Haddam, Conn.	350	2.0	Few	196	800	13	13	346
Pine Brook	Pokatapaugh, Conn.	460	7.0	Few	259	800	19	19	339
Hockanum River	Rockville, Conn.	Over 250	Short	79	680	1500	11	13	254
Hoosic River	Schaghticoke, N. Y.	100	1.0	635	Small	2210	4	5	70
Battenkill	Middle Falls, N. Y.	140	1.6	454	600 Acres	2170	2 or 3	5 to 8	——
Seneca River	Seneca Falls, N. Y. *	49	0.8	770	Large	1529	3 or 4	10 or 15	26-39
Keuka Lake Outlet	Penn Yan, N. Y.	277	6-8	187-213	17.5 Sq. M.	5980	——	6	63.5
Genesee River	Rochester, N. Y. *	255	2.0	2475	Lakes	8970	3	About 50	200±
Fish Creek	Schuylerville, N. Y.	100	1.0	258	6.8 Sq. M.	2200	2 or 3	4 or 5	60-90

* May also be considered as belonging to the hydraulic canal system of development.

under buildings or superior canals. The above described method may be called the *canal system of development.*

Throughout the New England States there are numerous small streams entering the larger stream valleys through narrow precipitous channels, and in many cases natural or artificial lakes exist on the highlands. At many such places a small steady volume of flow, under a great head, may be obtained at points bordering on the large valleys, which are the main highways of commerce. The pioneers selected these small steady streams and built mills on their banks to grind grain and saw lumber. Large water powers were left untouched because of the great cost of development and the impossibility of utilizing large volumes of water with the old-fashioned water wheels. Thus the sites of future cities were often determined by small streams, and industries were founded that have since vastly outgrown the water power on which they were at first dependent.

In the early days, as the industries increased in number, one dam after another was built along the stream. Often these dams are but a few hundred feet apart and there may be ten or twenty of them in a single village. As a rule, the crest of each dam is placed lower than the level of the tail race of the mill above by an amount sufficient to prevent backwater.

There is usually a loss of head, varying from a few inches to many feet, between every two dams. Usually the most desirable sites are first developed, and a considerable portion of the total fall is often left unused, or, if used, is afterward abandoned. The great cost of constructing and maintaining so many small dams is evident, and in view of the desirable location of the power, it appears that in many cases redevelopment under a single fall would pay a liberal return. This system of utilizing water power may be called *cascade* development.

Examples of the Canal System of Development

The examples given in Tables 1 and 2 have been chosen mostly because of historical or local interest. It is quite certain, however, that central station redevelopment would be a very profitable undertaking at a number of these places, as well as at many others not included in the list. In the tables it has only been possible to give a very meagre resumé of the conditions at each place. The permanent horse-power estimated is not to be considered as a close figure, but is given to convey an idea of the magnitude of power available. Of course the economical basis of development would in most cases be much greater. A comparison of columns 4 to 11 of Table 1 shows the wasteful method of development made necessary by the canal system where the water has to be taken to the mills, only a few of which can be so placed as to utilize the full available head. In fact, very many mills at these older developments only utilize from one-half to three-quarters of the fall. A few of these water powers will be described with a little more detail.

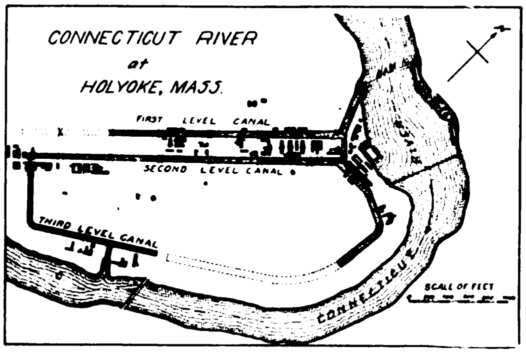

Fig. 1. Map Showing Development of Water Power on Connecticut River at Holyoke, Mass.

Fig. 1 shows the general scheme of development on the Connecticut River at Holyoke. A total fall of 61 feet is available in a distance of about 3250 feet below the dam. The raceways have a total length of 18500 feet, and occupy an area of nearly twenty acres. Most of the water is used on two levels, the total fall utilized being from 46 to 48 feet. The natural conditions are favorable for central station redevelopment, and by such a change the greater part of the canals could be abandoned and valuable land reclaimed where factories are now closely crowded. The permanent power could probably be increased one-fourth to one-third, the measurement and sale of power greatly simplified, and the use of surplus power facilitated and increased. Something like 150 turbines, many of them of old patterns, could be dispensed with, together with their attendant paraphernalia of screen racks, flumes, penstocks, wheel pits, draft tubes and harness. There are about sixty mills using approximately 30,000 h.p. during the day time and about one-half as much at night. Complete redevelopment is probably impracticable, as most of the power was originally sold on long term leases, carrying title to land for factory sites with water power.

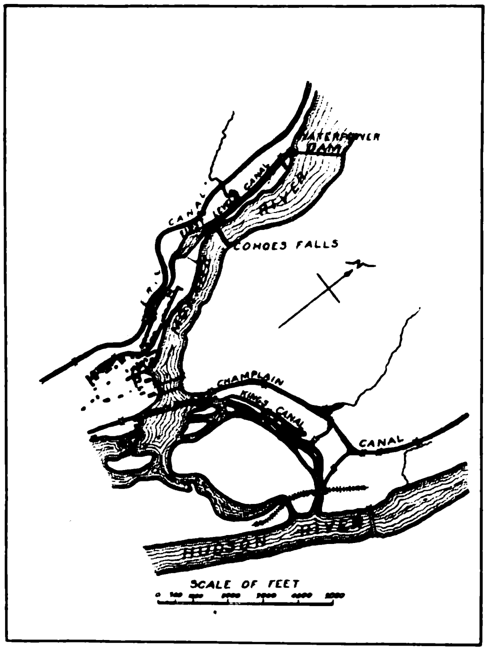

Fig. 2. Map Showing Water Power Development on the Mohawk River at Cohoes and Waterford, N. Y.

Fig. 2 shows the power development on the Mohawk river at Cohoes and Waterford. There is a total fall at Cohoes of 120 feet, of which 103 or 104 feet is developed. Nine canals are in service, having an aggregate length of 17,500 feet, and an area of about 22 acres. There are five levels, but the water is used under various heads, the principal combination of falls being 18, 25, 22.5, 19 and 19 feet, making a total of 103.5 feet. The horse-power of the wheels in use a few years ago was 6556. There are some thirty or forty mills, and the map fails to give an adequate idea of the complexity and number of raceways, wheel pits and turbines necessary to the use of the water on so many levels. The dam of masonry is a permanent structure, which cost $180,000, and the main or first level canal is admirably located for incorporation in a central redevelopment scheme. In fact, the cost of the power station and a short conduit would constitute nearly the entire expenditure necessary. Here, as at Holyoke, outstanding leases are a hindrance.

Fig. 2 also shows King's Canal on the fourth branch or "sprout" of the Mohawk as it debouches into Hudson River. Here are eight or ten mills operating under a low head, cramped for building room, and liable to inundation during freshets. The water rights appear rather uncertain, and the water level is sometimes drawn down in summer to the detriment of all. The Mohawk has four or five outlets, but only one of these is dammed, so that at best the water supply is limited. There are evident opportunities for improvement by redevelopment, but as is often the case on power canals, everybody's business is made the business of nobody, and matters stand as they were sixty years ago, although in the midst of a thriving and populous manufacturing district with admirable shipping facilities.

Fig. 3 shows the water power on Seneca River at Baldwinsville, N. Y. Here a low head of 11 feet is combined with the flow of a large and remarkably uniform river. A navigation canal on the left bank is also used as one of the raceways, and there are in all about ten mills, and forty or fifty turbines. Many of the turbines are very old scroll pattern wheels which have the reputation of disposing of all the water that can get to them, and are sometimes termed "water sows." There is no systematic control of the usage and draught of water—some mills have burned down, and the water flows unhindered through the abandoned flumes. The various leakage losses that I have repeatedly measured often aggregate 500 cubic feet per second, or more. I visited this place last summer at a time when the

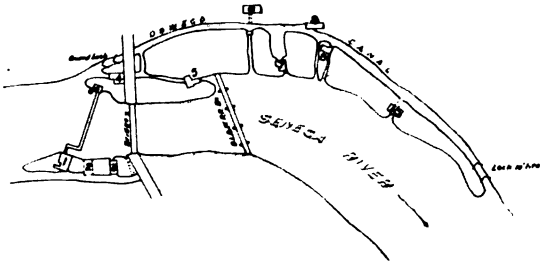

Fig. 3. Map Showing Water Power Development on Seneca River at Baldwinsville, N. Y.

water was drawn two and one-half feet below the flashboard crest, nearly one-fourth of the head thus being directly lost. The power could easily be redeveloped by using the existing masonry dam and one short canal.

The conditions at Black River, N. Y., shown in Fig. 4, are chosen as a single example of many apparently good opportunities for redevelopment in this important wood pulp and paper mill region. Here, as is often done elsewhere, a mill not reached by the flume or canal is supplied with power by wire rope transmission. A fall of 16 feet is available, yet some of the mills operate under heads as low as eight to ten feet. In this connection it may be noted that in the city of Watertown there is a total fall in Black river of 122 feet, seventy feet of which occurs within a distance of 4500 feet. This latter fall is at present developed by means of three dams, having fifteen hydraulic canals on four levels. There are twenty-five or thirty mills, and the total fall utilized in some cases is as small as forty feet, or four-sevenths of the available drop.

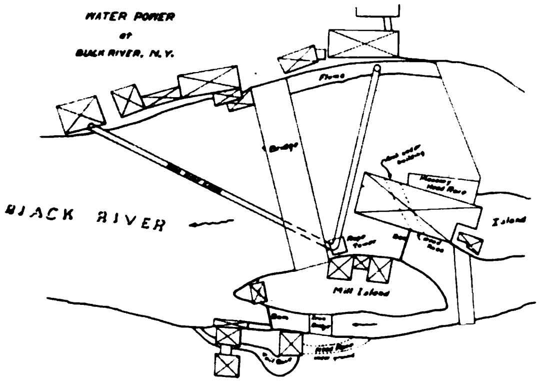

Fig. 4. Map Showing Water Power Development at Black River, N. Y.

Examples of Cascade Development

The data given in Table 2, like that given in Table 1, is chosen largely from the results of personal visits and investigations.

Fig. 5 shows the Battenkill between Middle Falls and Greenwich, N. Y. Here a fall of 140 feet could be obtained in a distance 1.6 miles. Redevelopment might be made by means of a power canal following the hill brow contour 350 feet from the dam to a point A, and thence a pressure conduit crossing the stream and leading to a power house at B. There are at present two or three dams where part of this power is used by several mills.

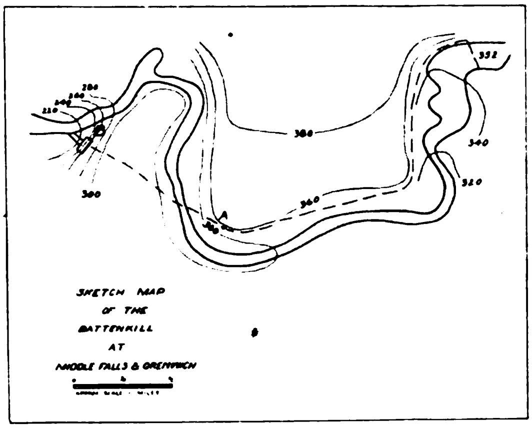

Fig. 5. Battenkill Between Middle Falls and Greenwich, N. Y.

Fig. 6 is a sketch map of the Hoosic river in the vicinity of Schaghticoke, N. Y., where a total fall of 100 feet occurs within an air-line distance of about one mile. Approximately 70 feet is at present developed by means of several dams. The dotted line AB shows a suggested course for a cross-country power canal, the water being led from B down the steep hill slope to a central power station at C, and thence discharging through an excavated channel into the river at D.

Fig. 7 is a sketch map of the outlet of Saratoga Lake at Schuylerville. Here again is a fall of 100 feet, now partly developed and used by several mills. The plan of redevelopment would be much the same as described for Schaghticoke.

Fig. 8 shows Lake George outlet at Ticonderoga, N. Y., where there is apparently an unusually good opportunity for redevelopment. The yield of a drainage area of 234 square miles is regulated by Lake George, which has an area of forty-five square miles. There is a total fall of about 225 feet, of which perhaps 150 feet is at present fully utilized at several dams. It appears that a power canal, about one mile long, could be constructed from A to B without difficulty, and the water conducted from the latter place by pressure conduits to a power house at C.

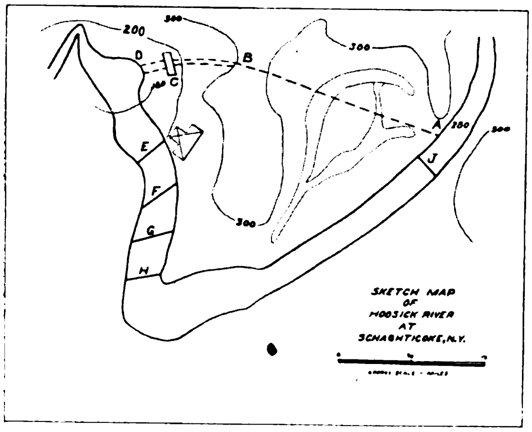

Fig. 6. Hoosic River in the Vicinity of Schaghticoke, N. Y.

Mutual Interference of Mills and Waste of Pondage

Where power is developed at successive dams under the cascade system, or where the same water is used on two or more levels in the canal system, the lower riparian owners are, in times of deficient water supply, largely at the mercy of those above.

I will illustrate some of the aggravating conditions that arise, such as have been the source of numerous and interminable law suits.

An upper owner A has a large pondage and runs his mill ten hours per day, utilizing a large part of the night inflow by means of pond storage. At a dam farther down stream B wishes to run his mill twenty-four hours per day, but requires less power than A. Under the conditions assumed he gets little or no power at night until A's pond has refilled, while he may be obliged to waste a large part of the day time flow past his mill. If A and B change positions the condition will be no better. Again, suppose there are on the same stream an electric plant running nights and a mill running daytimes, and that the uppermost has pondage sufficient to hold back the inflow when it is idle; it is evident that the lower plant may at times be deprived of almost all useful power. Consider a dozen successive dams, each with a pondage just large enough to control the low water flow for an hour or two, but with a total capacity sufficient to hold back a full day's flow. This is a case of quite common occurrence. Now consider these mills as operating through various hours, one requiring much power when another needs but little. It will be seen that the distribution of the power to the mills, especially those lower down, is a merry game of chance.

In general, the greater the diversity of conditions of use, the greater the waste by mutual interference under the cascade system of development.

In some cases of cascade development on streams fed by lakes, agreements or court decrees exist regulating the rate and time of draught from storage. This is at best a partial remedy, and virtually amounts to operating the mills to suit the power, rather than the power to suit the mills, as can be done with redevelopment under a single head.

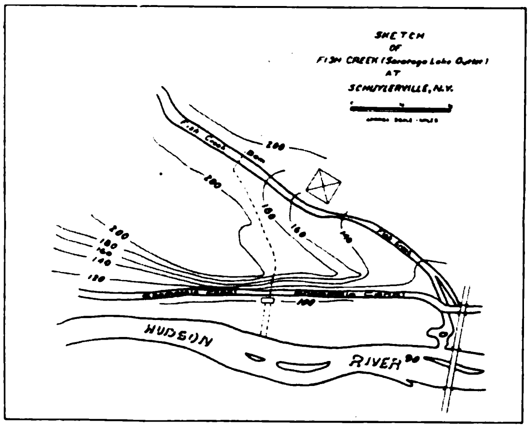

Fig. 7. Saratoga Lake at Schuylerville, N. Y.

The Theory of Pondage

Where mills operate only part of each twenty-four hours, say ten hours for example, it is a common practice to draw down the pond level during the running hours, and so utilize such a part of the night inflow as is required to refill the pond. Where there are several mills drawing water from the same dam, the water is often drawn down below the crest level to such an extent as to greatly reduce the head and effective power available.

With any given inflow rate Q in cubic-feet-seconds, initial head H in feet, hours run N, and pond area A in square feet, there is some depth D′ of pond depletion that will yield the maximum amount of power. By an application of the calculus the following expression for the depletion can be derived:

$$D' = \frac{AH - 1800\ NQ}{A}$$

For example, with $A = 5$ acres $= 217800$ square feet, $N = 10$ hours, $H = 20$ feet, and $Q = 200$ cubic feet per second, we find $D' = 3.47$ feet.

In other words, more power could be obtained during ten hours if the pond was drawn down a certain number of feet each day and allowed to refill at night, than if the drawing down of the head was either greater or less. In many cases the variation in the amount of power obtainable as a result of the varying utilization of pondage is very large.

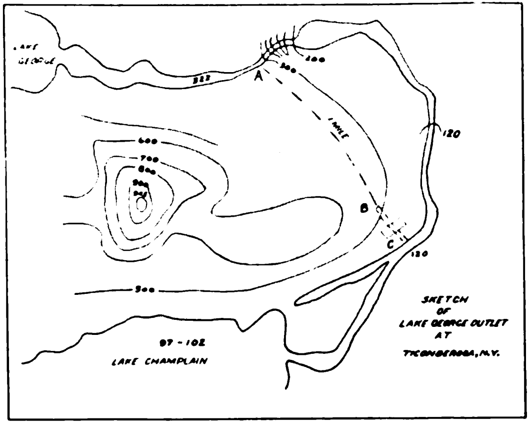

Fig. 8. Lake George Outlet at Ticonderoga, N. Y.

In canal and cascade developments the utilization of pondage is usually a matter of chance and guess work. With central station redevelopment, the power being under a definite control, economical use of pondage becomes practicable.

Measurement and Division of Power

To prevent the reduction of the head by drawing down the pond level, and to regulate other abuses sometimes incident to divided water powers, the regulation of the water supply to the mills is often placed in the hands of a commission or water-master. Under the most favorable conditions the division of a variable stream among several mills, running at different hours and with varying needs for water, it is a difficult matter. The water used cannot ordinarily be measured by weirs placed in the head and tail races without too great a loss of head. Submerged weirs are sometimes used, which cause a smaller loss of head, but these are usually less accurate and reliable than weirs with free fall. In other places the water used is estimated from a record of the head and run of water wheels at the mills. Daily measurements of the flow in the hydraulic canals by means of rod floats is the accepted method in several of the older water power centers. All these methods are costly and difficult to carry out, and the results are often unsatisfactory. With a central hydro-electric station both the total power delivered and the rate of use of power by each mill may be constantly open to inspection, and abuses can be regulated without awaiting the results of elaborate measurements and calculations.

Increased Efficiency from Redevelopment

Minor losses of head, such as are met with in power canals, screen racks and penstocks can be little reduced. Obviously there is little real difference whether six inches of head is lost on one-tenth the flow of a stream in each of ten canals, or on the entire flow in one canal, although there will be some gain in head by a reduction in the length of the canals, and by the use of clean racks, and canal gates and waterways of adequate size. A large gain in efficiency may often result from discarding antiquated, worn-out, poorly set and inefficient water wheels, many of which utilize only part of the head; and by the use of a smaller number of large wheels, mostly operating at full gate, to replace a greater number of wheels of promiscuous types and sizes, with their attendant losses by step friction and mill work. With individual power plants nearly every mill will have one or more wheels operating at part gate and low efficiency, while with a central power plant all the water wheels, excepting one or two, as a rule, can be operated at an average load and gate near to the point of maximum efficiency. Out of a total of 371 turbines in use in the Black river region in 1898, I found 101 which were ordinarily operated at part gate, while a much larger number were so operated at times. Of these wheels, 195 were not over 36 inches in diameter, and were largely used in wood pulp grinding where wheels of large capacity, operating at full gate, can be used to advantage. In one mill 36 old small register gate turbines were in use, doing work that might have been done by about one-fourth as many large modern wheels.

The better class of American stock pattern turbine water wheels have been developed from tests made at Holyoke, under a head of about 16 feet. For heads much greater than this it is probable that better results can be obtained by the use of wheels of special design. Redevelopment under a single head offers excellent chances for the development of hydraulic turbo-generator units, specially suited to the conditions, as is done with steam turbo-generator units.

Unused Water Privileges

At very many of the older power developments a portion—often one-fourth to one-half—of the water privileges have never been developed, or have been abandoned. Taken singly these unused privileges may be of little value, but collectively they often represent an important source of power in an ideal location.

Under the canal system of development, power belonging to unused privileges is often utilized rent free by operating concerns. Apparently such surplus power should be distributed among the various users. With the canal system the surplus usually goes to the plant that has the largest excess wheel capacity, and not infrequently, I regret to say, it goes to the biggest hog on the power canal.

In the cascade system of development by successive dams, the power at unused privileges is usually wasted. With redevelopment the unused privileges can be made productive, and the resulting power sold or equally distributed. The owners of unused privileges will usually co-operate in redevelopment, because it means to them a return on an otherwise idle investment.

Electric Power Distribution

The change in factory power distribution resulting from redevelopment may be little or great as desired. For example, the motor may be simply harnessed to the line shaft in place of the water wheels, or the main line shaft may be dispensed with and motors placed in each room or on each machine. If, however, an auxiliary steam plant is used the line shafting will usually be retained, though I apprehend that in most cases individual steam plants will gradually be discarded, and the auxiliary steam plant, if any is needed, placed at the central power station.

All the arguments in favor of electric power distribution versus mill work in factories are as applicable to mills supplied from a central power station as to those generating their own power. This is a field somewhat outside the limits of my subject, and I shall not enter it in detail. The following brief summary covers the main points:

The removal of lines of shafting, hangers, pulleys, etc., will result in decreased floor loads; increased room for and accessibility of machinery; avoidance of the large friction losses from mill work; reduction in repair and operation charges; and diminished fire and accident hazards.

Power need only be used when work is done, thus increasing the economy. Easier regulation will also result, as the throwing on or off of one machine will not affect adjacent machines. Reduced vibration, greater flexibility, and opportunity for use of yard and portable machines may also be noted.

Uncertain and Conflicting Water Rights

Having noted the advantages of redevelopment, it seems at first surprising that so little has been done in this field of hydro-electrical work. One obstacle to redevelopment may be found in the existence of uncertain and conflicting water rights, which gives rise to distrust, jealousy and an over estimation of their rights by individuals. With the water rights subdivided on a definite, fair and open basis, chances for selfishness would be reduced, and the matter of dealing with the water right owners would be greatly facilitated.

In the older power developments one of two plans was usually followed:

(1) Leases were granted to lands, carrying with them water under a head, as at Holyoke, Lowell and Lawrence in Massachusetts, and at Cohoes and on the Oswego Canal in New York.

(2) The original owner sold outright to

each purchaser the right to a certain power. These sales were made on different bases. In some cases the right was given to use a specified number of square inches of water under the available head where a square inch usually meant the theoretical flow through an orifice one inch square. In other cases the right was sold to use water enough to drive a mill, or to drive machinery or water wheels of some specified kind. Examples which have come to my notice illustrating the uncertainty of such deeds are, "water enough for the run of mill stone," "water enough for a blacksmith shop and a fulling mill," "water enough for a Johnston reacting water wheel as made in 1848."

In other cases the fractional method of partition is used, each riparian owner being entitled to so many fourths, seventeenths, sixty-fourths, or other subdivision of the total flow of the stream. The words "total flow" are intended to mean the minimum available flow in some cases, the average flow in other cases, and an arbitrary or assumed quantity in still other cases. As a rule the actual amount of power available was unknown when the deeds were granted. Such indefinite deeds pass from hand to hand and from generation to generation, using the original wording. The riparian owner draws as much water as he wants, as much as he can get, or as much as is allotted him, according to his influence and the disposition of his neighbors. Further complications arise from the once prevalent custom of granting first, second and third rights. Recently in visiting the mills on a power canal, every proprietor represented to me, and apparently honestly believed, that his was the "first right."

Organization of Redevelopment

The preliminary stage of redevelopment comprises the formation of a working agreement or consolidation among the water right owners affected. There are several ways of proceeding:

(1) By buying in the existing water rights.

(2) By the formation of a trust or holding company in which each riparian owner shall receive stock in proportion to his water rights.

(3) By a combination of the above methods.

In general, undeveloped or disused water rights should be acquired outright. Operating concerns are likely to object to yielding the control in their water rights unless an agreement is made to supply them with power. There is no reason why participating concerns should not be given first chance to lease the redeveloped power, but agreements to supply power in perpetuity or to supply any indefinite or unmeasured amount of power should be avoided. In these days of water power booms and promotion schemes, riparian owners get erroneous impressions of the value of their holdings and ask exhorbitant prices. Such inflation of values should be discouraged, as it leads to non-paying investments which are likely to reflect improperly on engineers. If redevelopment is undertaken by an association of the riparian owners, the difficulty at once arises of determining not only the actual, but also the relative rights of each. In the allotment of stock and the adjustment of a basis of profit sharing, jealousies and quarrels are apt to arise that will block the proceedings.

A case recently came to my notice where the riparian owners tried to come to an agreement as to their respective rights in order to join in the erection of a new dam. One man claimed 3200 square inches, although search failed to show that more than 2500 square inches had ever been deeded to him. The assembled owners finally agreed, however, as a last resort, to allow him 3200 square inches. Thereupon he talked the matter over with his wife and soon realized that the greater his water rights the larger share he would have to pay toward the dam, and then stubbornly refused to accept what he had asked for. I lament to record that his easy natured neighbors finally built the dam without his aid.

After the unification of water rights has been accomplished, redevelopment becomes a matter of engineering of an interesting nature. In general, the existing dam, lands and canals will be incorporated in the plans as far as they are of use. It will generally be necessary to so plan the work as to avoid interference with existing mills during the construction period. Most details of the construction are common also to other water power developments, and need not be specially treated here. I will, however, emphasize the value of a continuous gauging record of the stream flow, and the necessity for a more honest, thorough and logical determination of the economical size of development therefrom, than has commonly been made in power development schemes in the past.

PORCELAIN FOR ELECTRICAL PURPOSES

By E. L. Barringer

Within the past ten years the manufacture of porcelain for electrical purposes has become an important branch of the pottery industry, and a number of plants throughout the United States are engaged exclusively in its production. Porcelain as an insulating material occupies a field by itself, and probably more is made yearly than of all other insulating compounds combined, with the exception of rubber.

The characteristics which give porcelain its value to the electrical industry may be stated as follows: High insulating value; a vitrified structure which resists the entrance of water or moisture; refractoriness; resistance to oils, vapors, etc.; freedom from any tendency to warp, weaken or deteriorate in any way with age or severe service conditions; attractive appearance; ease of forming into various intricate shapes which are made permanent by firing; mechanical strength, with the exception of resistance to impact; and comparative cheapness. Other insulating materials may be superior to porcelain in this or that respect for certain purposes, but none combine to the same degree the qualities enumerated above.

Porcelain is differentiated from other ceramic products by its white color, impermeability, refractory qualities, and translucency in thin sections. Porcelain for electrical purposes is practically the same in composition as that used for high grade utilitarian and ornamental wares, and differs only in the form of the ware and the processes employed in molding it to shape.

Chemically, porcelain is a double silicate of potassium, or sodium, and aluminum. In some porcelains, lime is used as an additional base, and more rarely, magnesia. Feldspar introduces the potash, or soda, and alumina and silica; china clay and ball clay supply alumina and silica; and lastly, the additional silica needed is supplied by ground quartz or potters' flint. Thus the raw materials for porcelain consist usually of feldspar, china clay, ball clay and flint, used in the proper proportions to give the desired silicate when fired to a high temperature. The clays used are: kaolin or china clay, (a soft, white, refractory substance), and ball clay, (a buff-colored, very plastic material). China clay is very short, and cannot for this reason be used alone, which fact necessitates the use of enough ball clay to give the desired plasticity to the composition. On the other hand, ball clay cannot be used alone satisfactorily, owing to its yellowish color and its tendency to cause sticking in the molds and cracking of the ware during drying and firing.

Considered from the manufacturing standpoint, there are two classes of electrical porcelain—dry-process porcelain and wet-process porcelain—the difference being that in dry-process porcelain the mixture of raw materials is made to the form of a damp powder and pressed into shape in steel dies in screw presses; whereas in wet-process porcelain the raw material is mixed to a stiff mud or dough, made into a blank form, partially dried, and turned on a lathe to the final shape.

Dry-process porcelain is used for wiring fixtures, knobs, cleats, receptacles, attaching plugs, switch bases, etc. The parts shown in Fig. 1 indicate the field in which this quality of porcelain is used.

Wet-process porcelain is used for high tension insulation, such as is necessary for oil switches, transmission lines and transformers. This porcelain is more dense, and possesses a higher insulating value than the dry-process porcelain. As an instance of this, in one experiment the same composition, made up by both dry-process and wet-process, showed 1.7 per cent. absorption for the former method and 0.5 per cent. for the latter. Chemically, there is little or no difference between the two porcelains, but usually in the wet process a larger proportion of plastic clay (ball clay) is used than in the dry. This is to facilitate molding into the desired shape, wet-process methods usually requiring more "flow" to the body than dry-process because of difference of pressure in molding. Fig. 2 shows a group of wet-process porcelains.

With the exception of molding, the manufacture of the two classes of porcelain is practically the same, and the following description of the process applies to both, except where otherwise noted.

The raw materials—feldspar, china clay, ball clay and flint—are weighed out and conveyed to the blungers, which are cylindrical tanks containing horizontal arms revolving on a central shaft. Water is added to the mixture of raw materials in the blunger, and the mass is stirred or "blunged" until of the consistency of cream. The porcelain body in this liquid, creamy state is termed "slip." After blunging, the slip is run through a coarse sieve (which removes woody particles and other coarse matter), into an underground tank or agitator, in which revolving arms prevent any settling out of the porcelain materials. From this underground agitator the slip is pumped up and onto a fine sieve or lawn, which separates any particles coarser than 150 mesh. The sieved material falls into a second agitator, from which it is pumped to filter presses. In the filter press the water is removed from the slip by pressure, the porcelain mixture remaining in the press in the form of solid, damp cakes.

A view of the slip room in the porcelain shop of the General Electric Company is shown in Fig. 3. Individual electric drive is used, insuring cleanliness and order in the slip room, where it is highly desirable, and also permitting of the independent operation of machines which run intermittently, such as the disintegrators, pump and sieve. Any disturbance in any of the machines cannot affect the remainder of the system.

Up to this point the treatment is the same, whether the porcelain is to be wet-process or dry-process. The further preparation of the "body" or porcelain mixture now differs, according to the process for which the stock is intended.

For dry-process porcelains the damp cakes from the filter press are dried over steam coils until just the necessary moisture remains for pressing—about 20 per cent. by weight. The mixture, still in cake form, but not as damp as on coming from the filter press, is fed into a four-vaned disintegrator which revolves at a speed of about 1400 r.p.m., and which beats the mixture to a fine, loose, damp powder, in which form it is ready for pressing into shape. The pressing is accomplished in hardened steel dies, pressure being produced by a hand-operated vertical screw. Fig. 4 shows several of these presses of the larger size, requiring two operators. For the smaller presses one operator is sufficient.

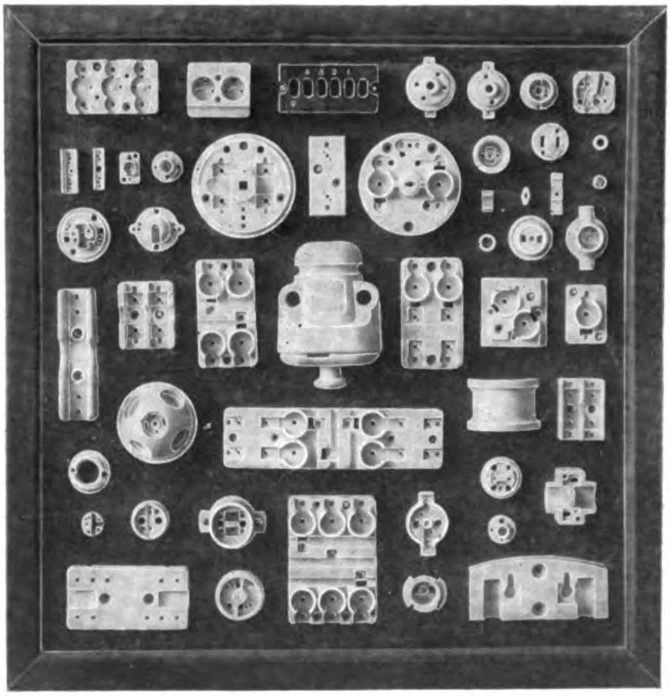

Fig. 1. Dry Process Porcelains

There are about 70 of these machines used in the porcelain shop of the General Electric Company, mostly of the Company's own manufacture, and about 1200 stock shapes are made, some of which require very complicated and ingeniously constructed molds. This equipment keeps a force of tool makers busy repairing old molds and making new ones as new designs require them. The damp clay powder "flows" well under pressure, and pieces of intricate shape, with thin walls and irregular recesses, can be molded without difficulty. In this respect porcelain has an advantage over other molded compounds which lack the plasticity of clays and will not flow so readily and uniformly under pressure.

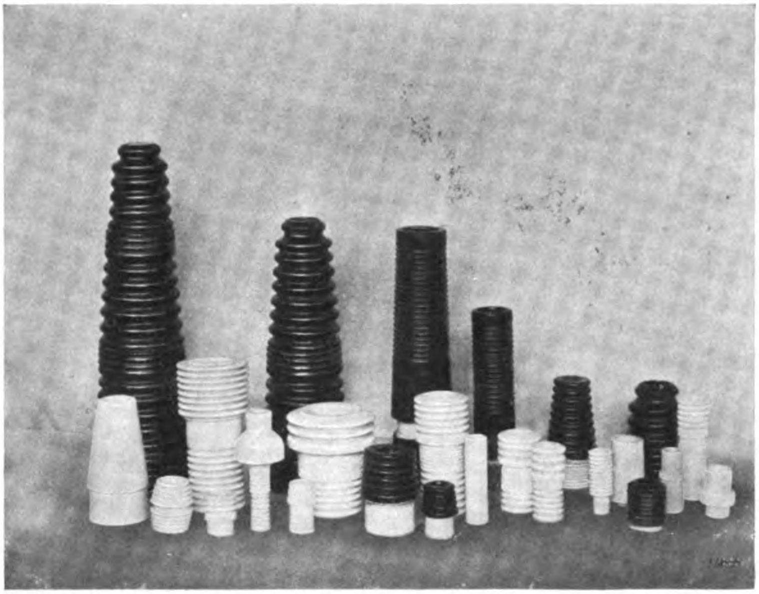

Fig. 2. Wet Process Porcelains

The molded pieces are placed on pallet boards, which are stored on drying shelves, or "stillages." Beneath these shelves steam pipes are located, which supply the necessary heat for rapid drying. The drying period occupies from a few hours to several days. After the "burrs" or "fins" occasioned by the joints between the mold parts have been removed from the thoroughly dried pieces by hand brushing, the glaze is applied to the surfaces requiring it. The glaze material is used in the form of a thick liquid, or "slip," which is either sprayed on the porcelain pieces, or into which the porcelain is dipped and quickly removed, either method leaving on the ware a thin coating of the green or "raw" glaze. The glaze consists of the same materials as the porcelain body; *viz.*, clay, feldspar and flint; with the addition of calcium carbonate or whiting, which lowers the melting point sufficiently to cause the glaze to run to a smooth, glassy layer at the same temperature at which the porcelain vitrifies. The porcelains are now ready for the kiln, but as both dry-process and wet-process are fired in the same way, the wet-process ware will be first followed to this point.

The porcelain mixture for wet-process ware is not dried on coming from the filter press, but the damp cakes are piled up in a large mass and smashed together with wooden mallets. From this pile the material is fed in chunks by hand into a vertical pug-mill, which "pugs" and kneads the clay to form a homogeneous mass and remove enclosed air. The mixture is forced from the bottom of the machine in a horizontal stream by an auger, and from this slowly-issuing stream, or column, of clay—which is about 8 inches in diameter—sections are cut off to be molded. The clay is now a soft, plastic mass, and the sections cut off from the pug mill are placed in plaster of paris molds, which are in turn placed in a "jigger." In this machine the soft porcelain body is forced to the walls of the plaster molds by a descending coring pin, operated by a "pull-down," and the blank cylinder is thus formed. After drying over night, the blank clay piece is removed from the plaster mold and is then allowed to dry on shelves over steam coils until in a "leather hard" condition. In this state it can be cut very easily (about the same as cheese), and at the same time is sufficiently strong to retain its shape under pressure of the tools. The final contour desired, including grooves, etc., is worked on the blank piece either in a lathe or on a vertical jigger. The cutting tools are peculiar to the clay industry, and consist of triangular, oval, and irregular-shaped scrapers or cutters, knives, sticks, etc. After cutting to the desired shape, the piece is sponged off to remove tool marks, and then placed on shelves to dry.

Fig. 5 shows a porcelain "blank" from the plaster mold, and one of the same blanks machined to the final form. The same piece is also shown after being fired. The material taken off in cutting to shape removes the fine surface drying cracks, or "folds" in the materials where jammed against the plaster mold.

Drying must be carried on with care to avoid cracking or checking. Though the ware may look white and dry, yet it is often not thoroughly dry inside and will crack when fired in the kilns.

With wet-process porcelains the drying occupies from one to six weeks. The dried ware is glazed in the same manner as the dry-process porcelain. A deep brown glaze is used on a large part of wet-process porcelain, this glaze being similar in constitution to the clear or colorless glazes, but containing coloring oxides which unite with the other ingredients of the glaze to form colored glasses.

The dried porcelains, both dry-process and wet-process, are placed in "saggers," (cylindrical, fire-clay boxes), and set in the kilns. The saggers are necessary to build up the ware in the kiln, and also to protect it from the fuel, gases, flying ash, etc., preserving the clean white body and smooth, glazed surface. They are made of a mixture of fire clays and have a coarse, open structure, similar to that of fire-brick. From 900 to 3500 saggers can be placed in each kiln, depending on their height, which varies from 2 to 10 inches. In addition to round saggers, a small proportion of oblong ones are used.

The kilns are of the old potters' type, bottle shaped, with outlet stack in the middle, and six or eight fire boxes around the base. Soft coal is used for fuel. Flues from the fire boxes lead radially to the center

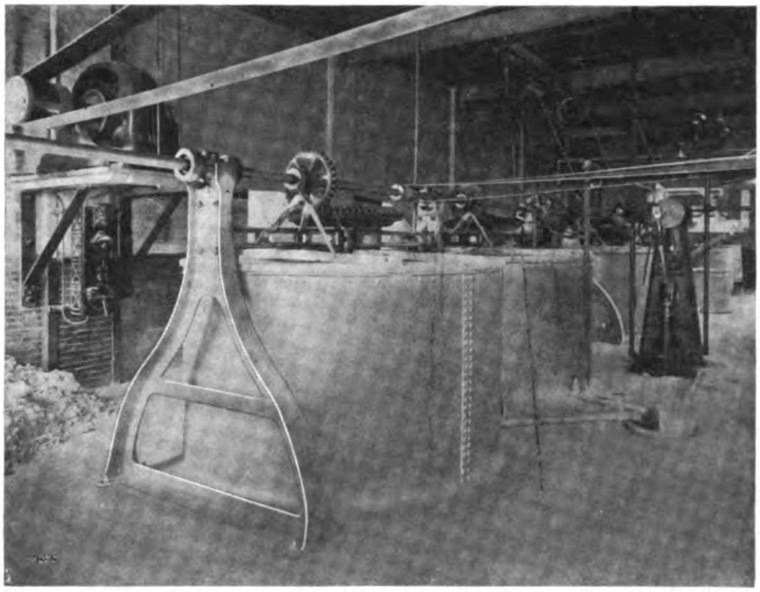

Fig. 3. Slip Room in the Porcelain Shop of the General Electric Company

of the kiln, and each fire box is also an outlet to the interior of the kiln over "bag walls."

The temperature is raised as rapidly as possible to between 1200° and 1400° C., and held at this point for some hours. The finishing temperature is determined either by glaze-color trials, shrinkage trials or pyrometer cones. The last named method is the one mostly used in the porcelain shop of the General Electric Company. The pyrometer cones are small, triangular cones, about 2½ inches high, composed of the same materials which enter into the porcelain composition, but varied in such a way that a series of cones is secured with softening-points ranged about 20° C. apart. A set of three cones is put in the kiln within the range of a "peep-hole," the melting-point of one of these cones corresponding to the desired temperature, while the other two cones soften or melt at 20° C. above and below this point. When the first, or most fusible of the cones has melted, indicating an approach to the proper temperature, the firing is carefully manipulated until the middle, or critical cone has softened and bent over, when the kiln is "shut off." The last cone of the series, or the most infusible, must not be melted down. A shrinkage of about 14 per cent. occurs in the porcelain mass during firing. On this account dies must be made proportionally larger than the sizes required in the finished pieces. The firing operation vitrifies the porcelain mass, or body, and fuses the glaze to a smooth, transparent coating. The firing period occupies from 25 to 45 hours, depending on size of kiln, quality of fuel, weather conditions, etc. A reducing fire gives the whitest porcelain, and the firing is usually of this character.

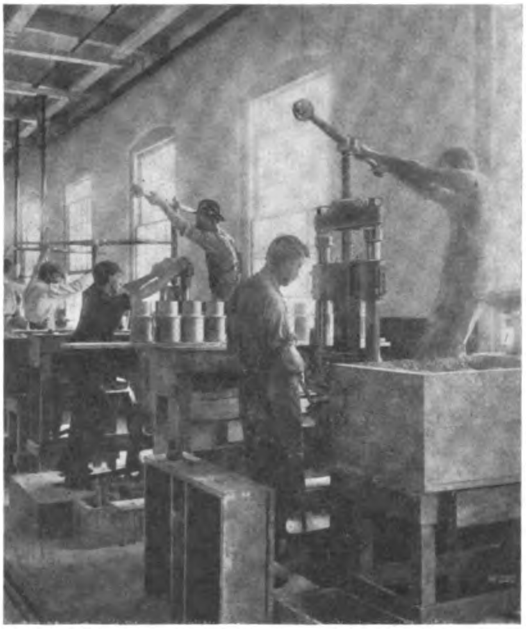

Fig. 4. Presses for Dry-Process Porcelains

If the proper temperature in the kiln is exceeded, the porcelains undergo too much shrinkage, and also become rough on unglazed surfaces and bubbled on glazed surfaces. Over-firing will also cause warping, distortion, and a bluish color. Underfiring results in imperfect vitrification, insufficient shrinkage, and a yellowish tinge to the color. The glaze on underfired pieces is dull and cloudy, instead of bright and transparent. It will be seen, therefore, that correct firing is extremely important, and determines whether the porcelain is to be good or bad, no matter how carefully the work may be done up to this point.

After the ware has been properly fired, the kiln is cooled rapidly and the porcelains removed and sorted.

Dry-process porcelains are removed to the shipping room, boxed and delivered to the department where they are to be assembled to form the various wiring fixtures. The burning is usually carried out with such regularity that the size of the porcelain can be depended upon within a certain small variation, and there is no difficulty in fitting together the porcelain and metal parts. A small percentage of the dry-process ware which must be unusually close to a certain size is gauged and sorted. No insulation test is required on dry-process porcelains. The vitrification and consequent non-absorption can also be depended upon regularly. The requirements specified by the General Electric Company for satisfactory dry-process porcelain may be stated as follows:

The variation in size above or below the dimensions called for must not exceed $\frac{1}{64}$ in. to the inch, except that knobs and cleats may vary in height $\frac{1}{32}$ in. to the inch. The porcelain must be well vitrified, and the absorption in an unglazed piece immersed in water must not exceed one per cent. by weight in 48 hours.

The porcelain body must be uniform and free from cracks or holes. The glaze must be bright and smooth, with no checks or pinholes, or thickening at the edges which would interfere with assembling. Glazes free from lead and such as use no lead salts for fluxes are required, as arcing tends to reduce the lead present to the metallic state.

The wet-process porcelains, on coming from the kiln, are first sent to be tested, and then to the various departments where they are assembled. Practically all of these porcelains are tested to insure their having the proper disruptive strength. The test voltage varies from 2000 to 125,000 volts, according to the purpose for which the insulators are to be used. It is a fallacy to suppose that increased thickness gives added disruptive strength. This is perhaps true within narrow limits; but, in general, increased thickness makes proper vitrification more difficult to accomplish, and the ware will contain small cracks and hollow spaces, which will break up the continuity of the mass and reduce its resistance to puncturing voltage.

The requirements for wet-process porcelains are: a thoroughly vitrified body which will not show over 0.25 per cent. absorption when immersed in water for 48 hours; a permissible variation in dimensions of $\frac{1}{32}$ in. to the inch, above or below the given size. The requirements for the appearance and character of the glaze are the same as for dry-process ware.

In testing wet-process porcelains a great many variations are employed by different manufacturers and users. For insulators used in high-tension oil switch apparatus, or porcelain bushings used in large transformers, the test is usually only a "dry" test, as these insulations are, of course, not subjected to rain or fog or other weather conditions affecting the insulation, the average factor of safety being 2½ to 1. A large proportion of insulators for this work are tested only in assembled apparatus, and no preliminary test of the porcelain alone is considered necessary.

In testing insulators used in high-tension transmission lines, both dry and wet tests are used, the former to insure the proper resistance to puncturing, and the latter to determine the correctness of the design for avoiding arcing under given conditions. One carefully conducted wet test is ordinarily sufficient for insulators of any one design, but every insulator manufactured must be tested as to its disruptive strength. The insulators are usually designed so as not to puncture or arc over dry, at a voltage from 2 to 2½ times that which will be carried in service.

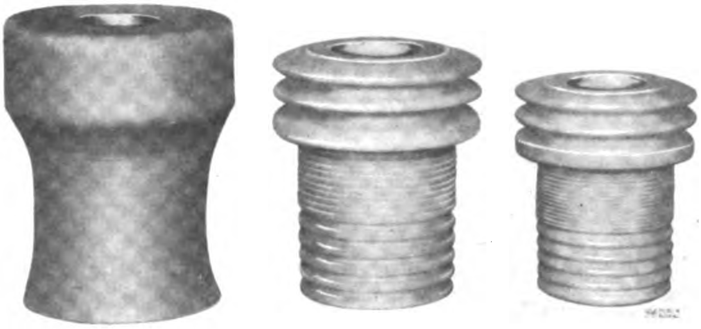

Fig. 5. Green Porcelain Blank; Same Cut to Shape; Machined Porcelain after Firing

There are various methods of applying the test potential, the average practice with insulators of the common petticoat type being to immerse the head of the insulator in water, and, after filling the pin-hole with water, to raise the potential between top and bottom until the test voltage has been reached. Salt water is sometimes preferred, owing to the better conductivity it provides from the metal terminals to the porcelain. In one factory making a specialty of high-voltage insulators, as many as 1800 insulators can be set up and tested at one time. Here a small chain is suspended into the water in the pin-hole, while the pan containing the water in which the head of the insulator is immersed forms the other connection.

Wet tests are made by applying a spray of water to the insulator, which is mounted on a pin, while the potential is raised. Arcing between the line wire and pin should not take place at less than the service potential, nor at less than any higher voltage which may be set by the engineer. The force of the water stream and angle at which it plays on the insulator are details subject to variation. To represent conditions of a rain and wind storm, the spray is sometimes applied at an angle of 30 to 45 degrees from the horizontal, or a fan is used to deflect a vertically falling spray, to cause it to strike the insulator at an angle.

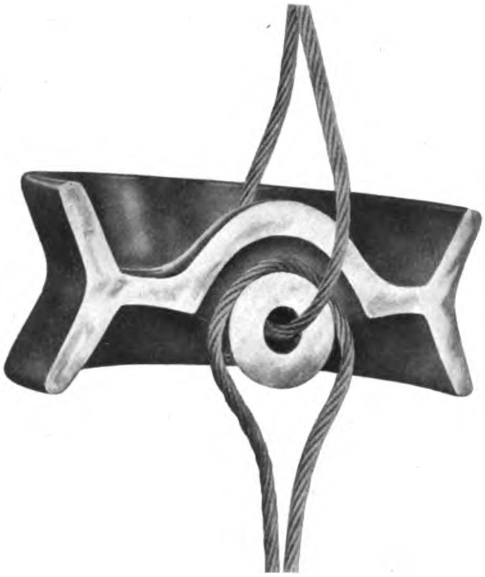

Fig 6. Cross Section of Link Strain Insulator

In testing the disruptive strength of multipart insulators, it is the practice to give each section a preliminary test before assembling, in the same manner as the complete insulator is tested, but at a proportional potential. In determining the potential applied in testing, both voltmeter and air-gap are used, some preferring one and some the other. While the voltmeter reading may not represent the maximum instantaneous potential, the air-gap potential, on the other hand, may be influenced considerably by atmospheric conditions.

Defective porcelain punctures with a violent cracking, the path of the puncture is heated, and a small globule of fused porcelain or glaze appears on the surface. Imperfect vitrification and the presence of checks or cracks, due usually to faulty drying or burning, are the principal defects causing the failure of porcelain in test.

Of the wet-process porcelains used for high tension transmission, the commonly used petticoat type of pin insulator is well known, and its merits and limitations well understood. Within the past year the insulators of the "suspension" type have been introduced, which are intended to overcome some of the defects of the pin insulator. Fig. 6 shows the General Electric Company's link suspension insulator in sectional view and in service assembly.

The advantages of an insulator of this type may be enumerated as follows: Higher electrical and mechanical factors of safety than heretofore obtained, resulting in the transmission of energy at higher voltages; flexibility of the system, avoiding torsional strains on the cross arm or insulators exerted by a cable swayed by wind; longer spans; simplicity of construction, and security in case of accident.

Porcelain used in high tension transmission must be of the highest grade, thoroughly vitrified, free from flaws of any kind, and strong mechanically. As stated before, porcelain is mechanically strong, except in the quality of toughness. It has very high resistance to crushing, and fairly high transverse and tensile strength. The resistance to sudden blow or shock is not so important in line insulators, which are well out of reach, as is the other quality of withstanding steady strains in any direction.

The respects in which porcelain fails to equal other insulating compounds, and which prevent its being a practically perfect insulating material, are its inability to withstand local over-heating without cracking; its lack of toughness and non-flexibility; the impossibility of imbedding metal parts within it; and, in some measure, its hardness. In arc deflectors or arc chutes porcelain would fail at once, through cracking and bursting, and finally through being fluxed by the arc. For such purposes a tough refractory compound, such as asbestos compounds, is much better suited, as this will neither crack when heated in spots nor flux readily with repeated arcing across the surface. The inability of porcelain to withstand impact or vibration under load renders it necessary to employ other materials for such conditions, such as hard rubber, asbestos compositions, and various molded compounds. As to imbedding metal parts in proclain in the same manner as in some materials, the high fire necessary to properly vitrify the porcelain prohibits this, because of the fluxing of the metal with the porcelain mixture which will take place at this temperature. The lack of flexibility in porcelain, and its hardness, prevent its being worked to any desired form after once being baked, and no alterations are possible.

However, with its shortcomings considered, porcelain is, as before stated, in a class by itself, and far ahead of all molded compounds in general value to the electrical industry.

HIGH VOLTAGE FUSES

By E. B. Merriam

Recent development on high voltage fuses and tests on 60,000 volt transmission lines indicate that many desirable combinations of a non-automatic switch and fuses are possible, the switch serving to open or close the normal load of the line and the fuses taking care of heavy overloads and short circuits. This provides a very economical arrangement where there is a moderate amount of power to be tapped from a transmission line, and where the expense of an automatic oil switch installation might be considered prohibitive. A fuse has not been considered as an effective protective device on high voltage circuits until recently. To be satisfactory for this class of work the fuse must be quick acting, so that synchronous apparatus will not be thrown out of step in case of short circuit on the transmission line, and it must open the circuit with no line disturbances. Past practice has demonstrated that open air fuses are unsatisfactory on account of the vicious arcs set up when a high voltage circuit is opened and the hot gases are unconfined. Air arcs at high voltages and hot gases which are of low resistance will involve adjacent conductors unless measures are taken to confine the disturbance. Such an arrangement complicates the station layout, and is only one of many of the objections to open-air arcs, These arcs are the origin of line disturbances. with the consequent break-down of insulation.

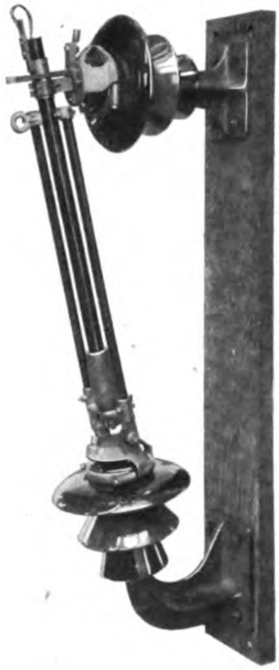

Fig. 1. Expulsion Fuse, Type T, Form D 60 000 Volts, 100 Amperes

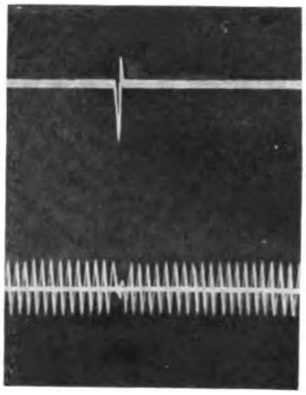

Fig. 2. Oscillogram Showing the Performance when Fuse Opens a Line Under Short Circuit

A fuse blown in a confined space, such as a non-conducting tube of suitable dimensions, proper consideration being given to the voltage, has the property of opening the circuit quickly, the arc being projected from both ends of the tube. This action can be improved if the tube is closed at one end and provided with a proper expansion chamber. Some designs introduce a moving element, such as a switch arm, which will elongate the path of the arc and thereby shorten the length of tube required, but this is undesirable as it introduces a long whipping air arc in series with the expulsion tube, and defeats the very purpose which was to be accomplished; namely, avoiding an open-air arc when the fuse blows.

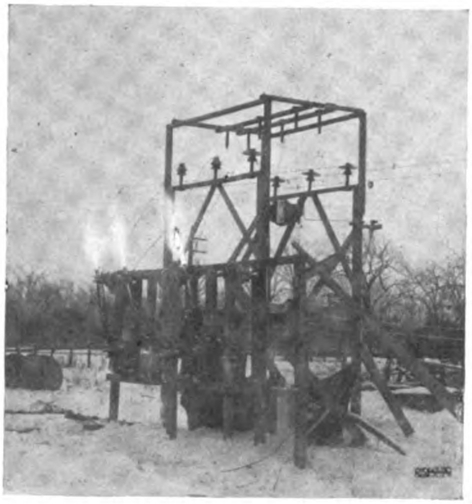

Fig. 3. Fuses Opening Short Circuit on 60 000 Volt System

To meet the demand for a fuse that will avoid all these objections and open the circuit with the least disturbance, the General Electric Company has developed the Type "T" Form "D" expulsion fuse and disconnecting switch. The fuse holder (Fig. 1) consists of a long re-enforced fiber tube, one end of which is inserted in and closed by a large hollow receptacle termed the "expansion chamber." The fuse wire or ribbon is fastened to a plug in the bottom of the expansion chamber, and from this is passed through the expansion chamber and tube and connected to a top clip provided for the purpose. The fuse has a reduced section in the expansion chamber to insure blowing at this point. The entire device is insulated from ground by standard line insulators, thus avoiding any complication in installation. The cradle and fuse holder are so designed that the combination can be used as a disconnecting switch, and magnetizing currents of transformers can be broken, and if necessary, immediately switched on without re-fusing or any operation other than simply throwing the switch. Of course there is a considerable arc projected from the open end of the tube when the fuse blows, but this is not objectionable, as it consists of the fuse metal and is not a power arc. Tests on this type of fuse indicate that the circuit is opened in from one-half a cycle to three cycles, and that with the momentary reduction of voltage due to the short circuit, synchronous apparatus will not drop out of step.

Referring to the oscillogram (Fig. 2), it will be observed that the circuit was opened near the zero of the current wave, the entire operation occupying only .02 of a second. Fuses of this type have been tested on 30,000 and 60,000 volt circuits under varying conditions, and have given great satisfaction. Some of the larger fuses will take a longer time to blow, but if the conditions are known beforehand the results can be controlled.

Fig. 3 shows the action of these fuses opening a short circuit on a 60,000 volt system.

Fig. 4 illustrates the action of an expulsion fuse on a 30,000 volt circuit.

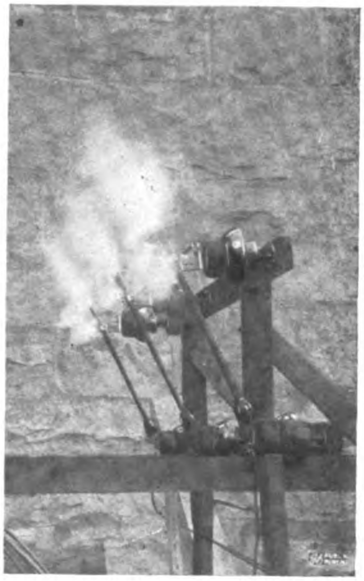

Fig. 4. Expulsion Fuses Opening Short Circuit on 30 000 Volt System

Tests have been made on sub-station feeders protected by 3 ampere fuses of this type, and the defective feeder was cut off without shutting down the main system. The voltage at this time dropped very low momentarily, but did not at any time rise above the normal value.

ELECTRO METALLURGY OF IRON AND STEEL

Part II

By Samuel A. Tucker
Adjunct Professor of Electro-Chemistry, Columbia University

KJELLIN PROCESS

This process for the production of high grade steel was first introduced at Gysinge in Sweden, and has the great advantage over other electric processes of working without electrodes, thus preventing the introduction of any impurities that they might contain, as well as increasing the carbon content of the resulting steel. Indeed, it may be said that steel made by this process is of the very highest quality.

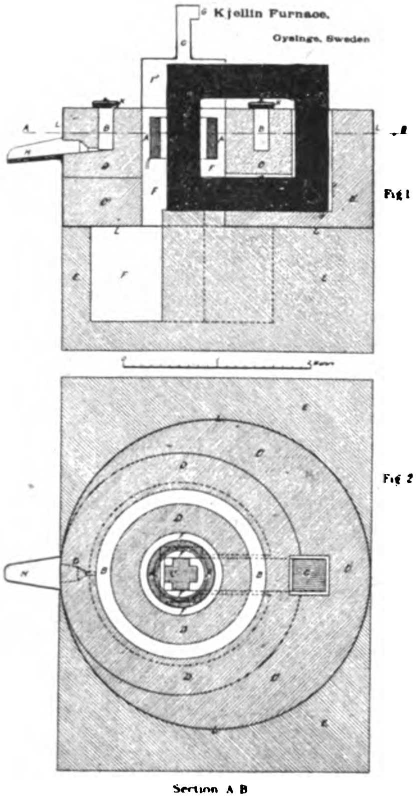

Fig. 1. Elevation and Plan of Kjellin Furnace

The Furnace

Fig. 1 shows both plan and elevation of the furnace, which is really a step-down transformer in which the secondary consists of a single turn of the metal to be treated. The figure gives a drawing of a 225 h.p. furnace, and shows the circular brickwork D, supported by the iron casing L, to be about 10 ft. in diameter. The annular space F retains the one leg of the core and the primary winding A. The secondary is formed by the channel B, which is on a level with the working floor and is provided with the detachable covers K, the charging being done by removing these covers.

Such a furnace will give an average output of steel of 4100 kgs. per 24 hours, with a power consumption of 165 kw., although the loss of heat by radiation is considerable, amounting to about 50 per cent. The temperature of the metal at tapping is from 1600 to 1700 degrees C, but the heating is under very perfect control.

The primary winding of this furnace is built for 3000 volts, the insulation consisting largely of mica, while ventilating spaces and water cooling devices are provided to prevent overheating.

Later furnaces, such as the Colby furnace in use at Philadelphia, operate at low voltage on the primary, the winding consisting of copper tubing through which water is circulated.

The method of working for the production of a high carbon steel for the Canadian Commission was as follows:

Composition of the Charge:

	Kgs.
Pig Iron	300
Steel scrap	125
Bar scrap	600
Metal in the furnace, estimated	700
12% Silicon pig	30
80% Ferro-manganese	1
	1756

Composition of Pig Iron:

Carbon	4.400%
Silicon	0.080
Sulphur	0.015
Phosphorous	0.018
Manganese	1.000
Copper	0.015
Arsenic	0.035

Composition of Bar Scrap:

Carbon	0.200%
Silicon	0.030
Sulphur	0.003
Phosphorous	0.009
Manganese	0.120
Copper	0.008
Arsenic	0.035

The charge was added gradually, some slag being removed as the process progressed. At the end of six hours the metal was ready for tapping, for which purpose the heat was raised towards the last.

The cast ingot weighed 1030 kgs., some of the metal being held in the furnace for the next run, as a metallic circuit has to be maintained in the secondary at all times.

One ton of product takes 2053 lbs. of material, and the energy required for working this particular charge was 857 kw. hours, equal to 0.116 h.p. years per ton of steel produced.

Composition of the Product:

Carbon	1.082%
Silicon	0.194
Sulphur	0.008
Phosphorous	0.010
Manganese	0.240
Arsenic	0.012
Copper	0.031
Aluminum	Trace

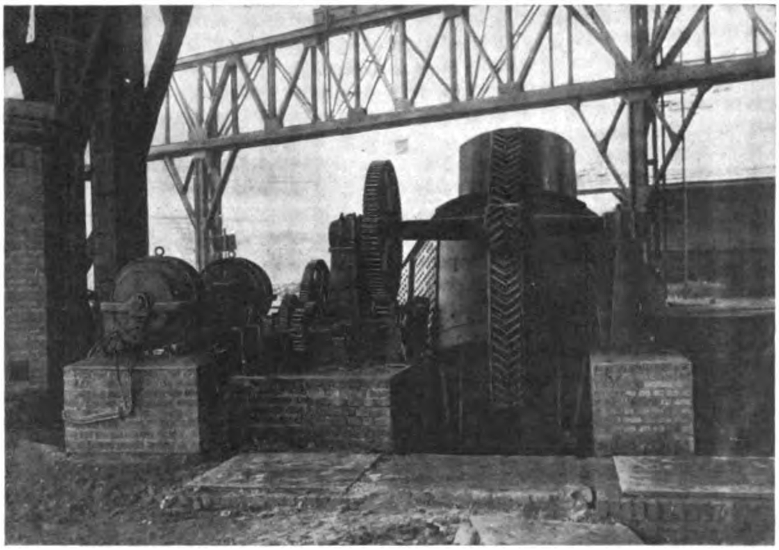

Fig. 2. 736 Kw. Induction Furnace, Showing Tilting Mechanism
(Copyrighted by American Electric Furnace Co.; reproduced by permission)

The quality of the steel produced by this process is the very best, and ranks with the highest grades of crucible steel; indeed, the process is nearly identical with the best crucible practice, and is conducted with much greater economy. Moreover, the control of the whole operation is very perfect.

From recent experiments carried on in Germany with induction furnaces now in operation, it is found that the removal of the sulphur is a simple matter, and that it is best to have the charge low in phosphorous if a low carbon steel is desired. If the removal of carbon is not an object, the sulphur and phosphorous can be reduced to traces. The furnaces are preferably made tilting, so that the contents may be poured, which is a better arrangement than that of the original Kjellin furnace using a fixed position with a pouring channel. In the German plant these furnaces have a capacity as high as 24 tons per day. Economically, it is only possible to use a fluid charge, which is first melted in a separate furnace and then delivered molten to the induction furnace. It seems, therefore, that this process has a distinct future in being able to handle open hearth product in the molten condition which is to be converted to the higher grades of steel.

A small induction furnace manufactured under the Colby patents, with a capacity of 190 lbs. of steel, was put in operation at the Disston Saw Works at Philadelphia, and was so far successful as to manufacture steel of such quality as to meet the exacting demands of the company.

It is found best to use currents of low frequency on the primary of the induction furnace, in order to compensate for the low power factor. This means more expensive machinery for the generating plant, but notwithstanding this drawback, there is very great economy over the crucible process. With the induction furnace the casting of large ingots is a matter of great ease, which is a very obvious advantage, as uniformity is attained with a minimum amount of labor.

Figs. 2, 3 and 4 show views of 736 kw. furnaces recently installed at the Roechling Iron and Steel Works in Voelklingen, Germany. Figs. 5 and 6 are two views of a 450 kw. induction furnace; while the illustration on the cover of this issue of the REVIEW shows the 60 kw. furnace in operation at the Disston Works at Philadelphia.

KELLER PROCESS

This process is applied primarily to the reduction of iron ores for the production of pig iron, and has been in operation at the works of Keller, Leleux & Company at Livet, France, for some time. Steel making is also carried on by this company, but their electric steel furnace is so similar to the Heroult steel furnace that a description is unnecessary. The Keller furnace for the reduction of iron ores presents considerable originality, the heating being accomplished both by the arc and resistance principle. Fig. 7 is a diagram of the two hearth furnaces, and Fig. 8 shows a general view of the same furnaces, which consist of an iron casing of square cross section with refractory lining. The two square shafts of the furnace are connected by a channel which is filled with molten metal when in operation. The electrodes are arranged vertically, and have a cross section of 28 in. On the bottom of the furnace is placed a slab of carbon for use in starting the furnace, the path of the current being from one electrode, through the charge to the carbon slab of one shaft, then by outside metallic connection to the carbon slab in the second shaft, thence through the second charge and electrode.

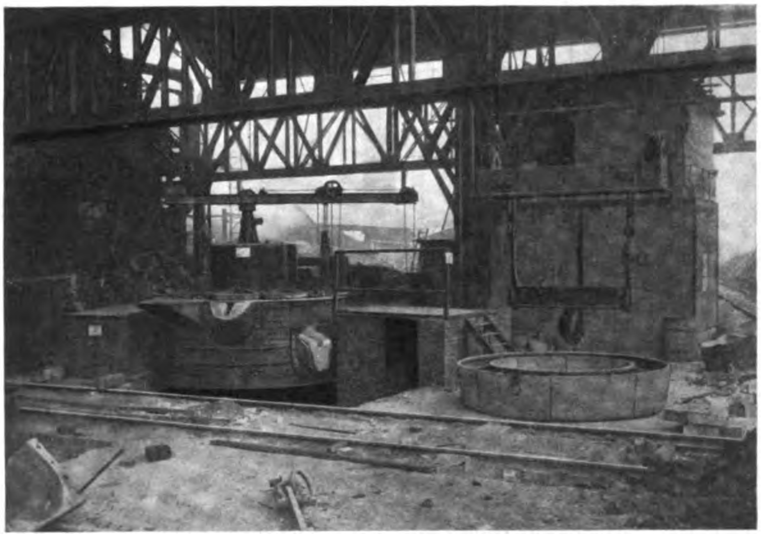

Fig. 3. 736 Kw. Tilting Type Induction Furnace
(Copyrighted by American Electric Furnace Co.; reproduced by permission)

After the furnace is in operation the molten metal collects in the hearth immediately above the carbon slabs, and also circulates in the channel connecting the two, so that the bulk of the current is carred directly through the channel. This arrangement facilitates the removal of the molten metal and slag, and at the same time does not hinder the working of the furnace during this dis-

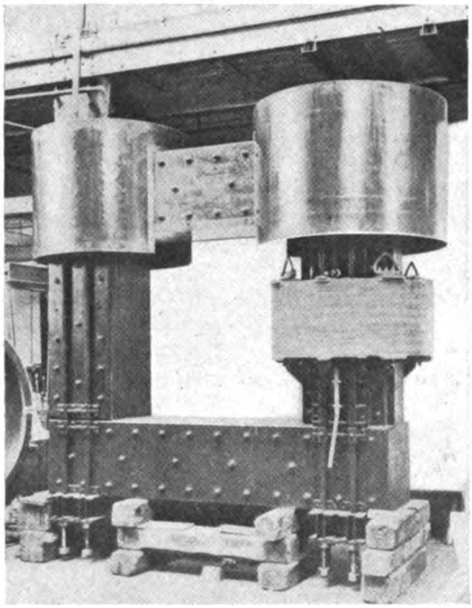

Fig. 4. Transformer of 736 Kw. Induction Furnace
(Copyrighted by American Electric Furnace Co.; reproduced by permission)

charging, as the current during this time is again carried by the outside shunt circuit.

The heating is accomplished largely through resistance, for as the charge is introduced the electrodes are raised, and the reduction of the ore proceeds very regularly and is facilitated by the passage of the hot gases ascending from the hotter zones of the shafts. In the later type of furnace (Fig. 9), this effect is particularly sought, the shaft being built longer, thus economizing the thermal energy. The figure shows a furnace with four hearths and one central well, the electrical connections being on the same plan as for a furnace having two hearths.

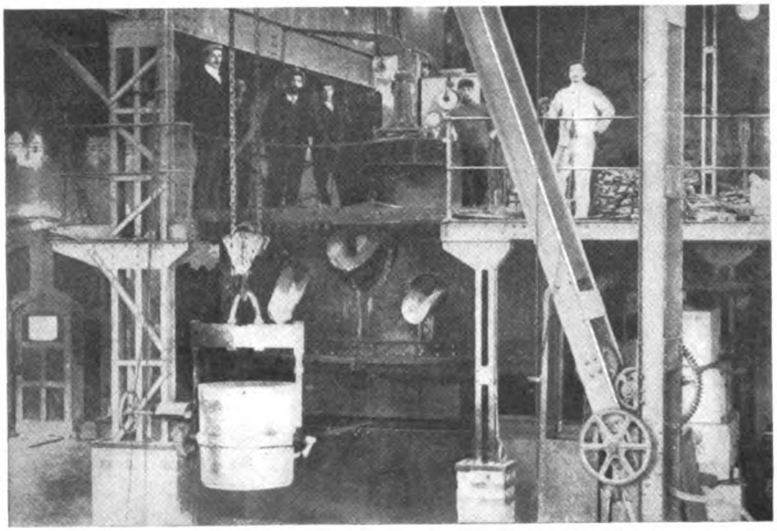

Fig. 5. 450 Kw. Induction Furnace, Front View
(Copyrighted by American Electric Furnace Co.; reproduced by permission)

It has been found that the use of resistance heating of the charge itself makes it easy to obtain control of the temperature, so that the process is carried on quietly and with ease. Regulation of the electric energy is effected by changing the elevation of the electrodes, thereby increasing or decreasing the resistance.

The furnaces are of considerable size and are designed to absorb about 400 to 600 kw., the current being from 6000 to 11000 amperes.

Although the smelting of iron ore was the chief object in the design of the Keller furnace, it has been used successfully for the production of ferro-alloys, such as ferro-chromo, ferro-silicon, and the like. Several runs were made at Livet to demonstrate the smelting of iron ores for the Canadian Commission, and very careful data was secured, with special attention to the following points:

1. The output of pig iron for a given consumption of electric energy.
2. The yield of metal per ton of ore charged.
3. The quantity of coke required as a reducing agent.

4. The quality of pig iron obtained, with reference to its suitability for the various metallurgical processes for which it was subsequently destined. The ore contained:

Metallic iron	48.690 per cent.
Phosphorous	0.011 " "
Sulphur	0.020 " "
Silica	2.700 " "

This was mixed with coke, lime and quartz to form a suitable mixture, and was charged down the shafts around the electrodes. The operation was carried on for 55 consecutive hours, a total of 23466 kgs. of mixture being treated in this time.

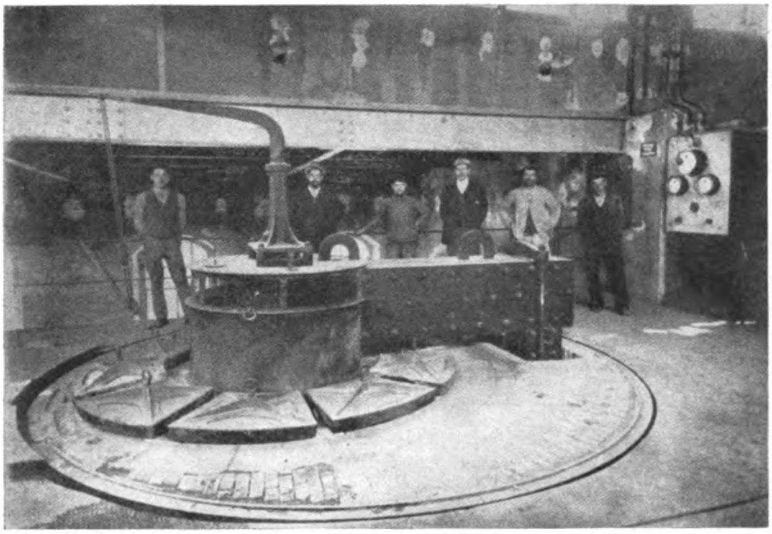

Fig. 6. 450 Kw. Induction Furnace, Top View
(Copyrighted by American Electric Furnace Co.; reproduced by permission)

From this charge 9868 kgs. of metal were obtained, with a production of 2025 kgs. of slag. The metal had the following average composition:

Total carbon	4.200
Combined carbon	0.800
Graphite	3.420
Silicon	1.910
Sulphur	0.007
Phosphorous	0.027
Manganese	4.300
Arsenic	Trace

The electric energy consumed per ton of pig was 0.475 e.h.p. year, which at $10.00 per e.h.p. year amounts to $4.75 per ton of metal produced.

Subsequent runs were made to ascertain if it was possible to obtain other grades of iron by varying the proportion of the charge, and this was found to be the case. The results of the experiments were also found to agree very closely with the workings of an ordinary blast furnace, and about the same changes in the product could be brought about by the means usually employed in ordinary metallurgical practice. An estimate of the cost of the process per ton of pig iron produced, was made by Mr. Harbord, who compares it to modern blast furnace treatment, as follows:

ELECTRIC SMELTING		BLAST FURNACE	
Ore	$2.76		$2.72
Coke, 0.34 ton	2.38	0.925 ton	6.40
Electrodes	.77		
Lime, 400 lbs.	.40	400 lbs.	.40
Labor	.94	American practice	.42
Electric energy at $10 e.h.p. year	3.50		
Steam raising for blowing engine			.10
Miscellaneous materials			1.30
Repairs and maintenance	1.30		
	$12.05		$11.34

THE GEROD PROCESS

This process is one for the production of steel, and is in operation at the Société Anonyme Électro-Métallurgique at Ugine in France.

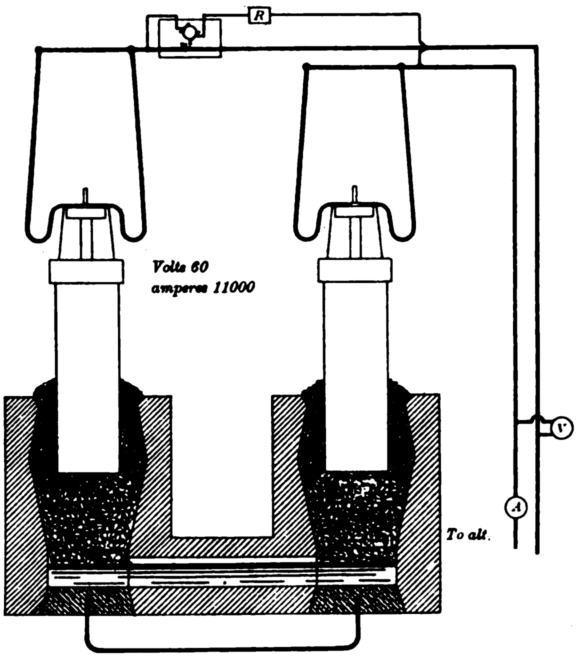

Fig. 7. Diagram Showing Electrical Connections of Keller Furnace with Two Hearths

While the chief object of this process is to manufacture ferro alloys, the furnace is well adapted for, and has been successfully operated as an electric steel furnace.

The furnace (Fig. 22), is of the arc type, having a single vertical electrode for one pole so far as electrical connection is concerned, but which actually is split up into four units all connected with the same lead. The body of the furnace is cylindrical and consists of an iron casing lined with magnesia brick, the bottom of which is provided with several hollow masses of iron, cooled by water. These iron masses serve as the other pole, and the arc takes place between the upper electrode and the slag floating on top of the reduced metal.

It will be seen that the furnace is very similar to the Heroult steel furnace, and the operation of refining is much the same as that called for by the Heroult process, in so far as the changing of the slags and their removal is concerned. The furnace is arranged upon trunnions for the purpose of discharging, and it is said that the use of one electrode makes the operation exceedingly simple. The exact details of the working of the Gerod process have not been published, but it is claimed that with a 250 kw. furnace one ton of steel has been produced in 4 ½ hours, using 1½ tons of charge with an expenditure of 1060 kw. hours of electric energy.

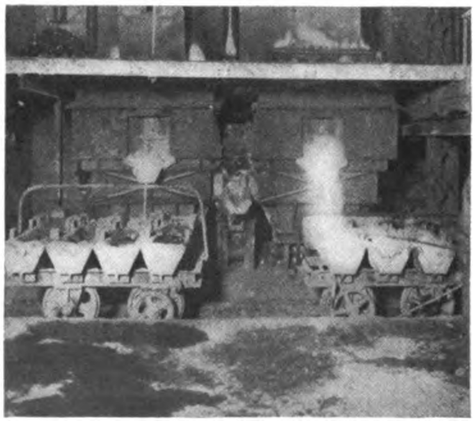

Fig. 8. General View of Keller Furnace with two Hearths

The processes which have been described are the most important, because in most cases authentic figures have been published of the actual working, and they are all on a commercial basis. This cannot be said of several other processes of which much has been written, but of which only little is actually known. For this reason we have not described the Gin, Stassano, Conley, Harmet processes, etc., as it would be only confusing to the subject, giving no information based on actual commercial working.

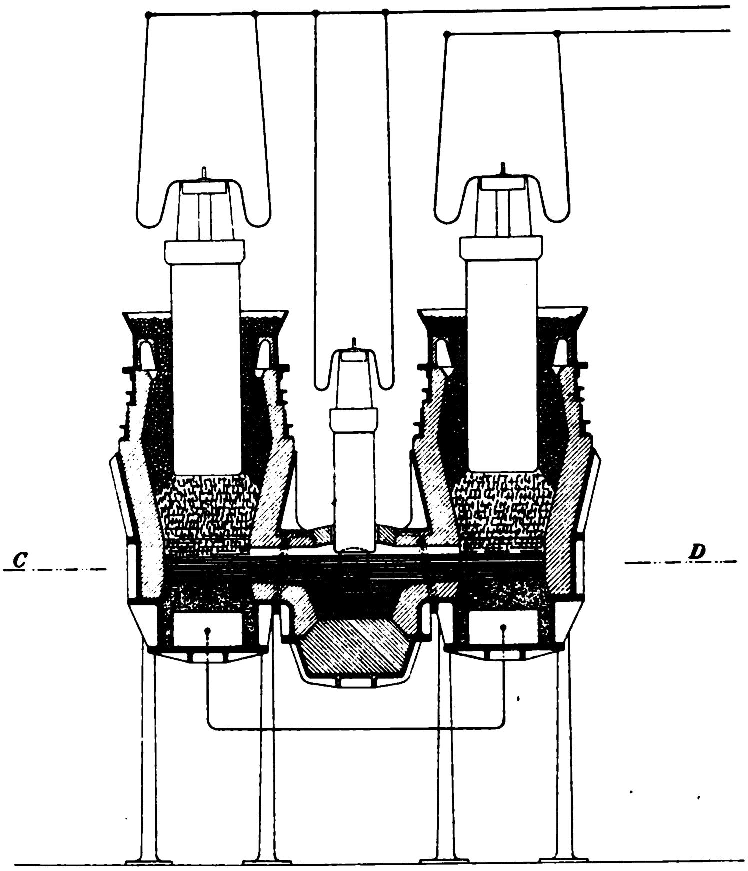

Fig. 9. Keller Electric High Furnace with a Plurality of Hearths

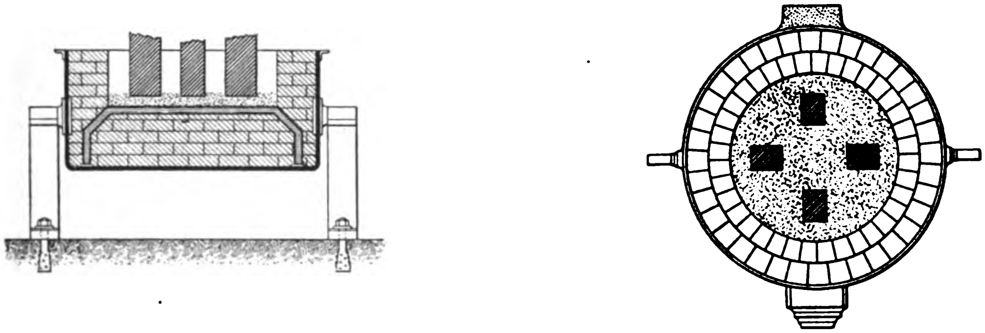

Fig. 10. Sectional Elevation and Plan of Gerod's Furnace

A comparison of the energy consumed in the important processes would rank about as in the following table:

HEROULT STEEL PROCESS*

Energy Consumed

Charged Cold

No. 1. 653 kw. hours per 2000 lbs. (Canadian Commission)
No. 2. 882 kw. hours per metric ton (2204 lbs.) (Goldschmidt)
No. 3. 1000 kw. hours per 2000 lbs. (Canadian Commission)
No. 4. 1000 kw. hours per 2000 lbs. (Canadian Commission)

Charged Hot

No. 5. 360 kw. hours per metric ton (Eichoff)

HEROULT REDUCTION PROCESS

No. 1. 3080 kw. hours per 2000 lbs. (Canadian Commission)
No. 2. 2306 kw. hours per 2000 lbs. (Haanel)
No. 3. 2342 kw. hours per 2000 lbs. (Haanel)

KJELLIN STEEL PROCESS

No. 1. 970 kw. hours per metric ton (Goldschmidt)
No. 2. 966 kw. hours per metric ton (Neumann)
No. 3. 757 kw. hours per 2000 lbs. (Canadian Commission)
No. 4. 947 kw. hours per 2000 lbs. (Canadian Commission)

KELLER STEEL PROCESS

Charged Cold, Using Ore

No. 1. 2800 kw. hours per metric ton (Goldschmidt)

Charged Cold, Using Pig Iron

No. 1. 730 kw. hours per 2000 lbs. (Canadian Commission)

KELLER REDUCTION PROCESS

No. 1. 3110 kw. hours per 2000 lbs. (Canadian Commission)
No. 2. 1475 kw. hours per 2000 lbs. (Canadian Commission)

GEROD STEEL PROCESS

No. 1. 1060 kw. hours per metric ton
No. 2. 1440 kw. hours per metric ton

The actual cost of the operation as conducted by the above processes varies anywhere from $6.00 to $35.00 per ton of product; and although at first sight this is hardly a satisfactory showing, it must be remembered that several conditions enter into the question. The factors which influence the cost of the operation are: size of plant, quality and cost of raw material, and power costs; and these vary considerably. Added to this, we have the results based on a small number of actual experiments.

There is little doubt that when any of these processes come to be conducted on a more extended scale, we may expect more encouraging figures, which will tend to extend this new industry very materially.

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*The Electric Furnace in Iron and Steel Production by J. B. Kershaw.

CURRENCY AND FINANCE*

PART I

BY HENRY W. DARLING

TREASURER OF THE GENERAL ELECTRIC COMPANY

This is a subject that is engrossing a great deal of public attention at present, and one that is somewhat mystifying to the average reader of the newspapers because of the technical terms used. I am fortunate in having had my subject mapped out for me by interrogations that have been made to me and which I find, after a little examination, fairly illustrate the difficulties of the average reader.

I will give some of the questions as an introduction:

How are National banks organized?

How do they issue currency?

How can a National bank increase its currency issue?

What relation exists between National bank currency and government and other bonds; and also government currency?

How is currency increased by importation of gold?

What are the means employed in distributing gold among National banks, and how is it converted into currency?

What is the practical operation of the National bank clearing house?

What are the actual practical operations of the National banks in face of a currency stringency, and what are the problems they face?

What is the process from special government action to relieve stringency to the point of actual currency relief?

How does our National bank system compare with those of England, Germany and France?

How would our system be affected by establishing a Government bank?

We will first consider the question, "What is money?"

One definition of money is, that it is a trustworthy, easily circulated and promptly redeemable token, used in exchange for commodities or service.

The function of money is to facilitate exchanges; it is the common medium by which these are rendered feasible. There has been, since the beginning of days, a division of employment and labor. Each one must live by exchanging his products for those of others. No one man could manufacture all the products or things that he needed for his own use or for the use of his family; therefore it was necessary to have a medium of exchange.

There must be a standard of comparison of the worth and value of articles or labor exchanged; and the adoption of some one commodity as a standard renders this comparison of values easy. The chosen commodity then becomes the common denominator in terms of which we measure the value of other goods or commodities. Money makes exchanges easier by making them definite, and has resulted in an increasing tendency of people to trust each other. It offers an approximate means of estimating the present value of a future act—a standard of value of deferred payments—and so it comes about that money is called a "legal tender"—the standard by which future obligations are determined. The sum and substance of all modern commerce and business is the exchange of commodities and circulation of tokens, and these tokens are called money; they may have intrinsic value or they may not.

The worth of money depends on its ability to carry out its face value. Gold and other metals are used for the purpose because they have in themselves an intrinsic or commodity value in the arts; they are less destructible than paper, silk, wood and glass, and their use commended itself to the people. These tokens we call money must be stable in value, must be trustworthy, and must be instantly redeemable in commodities and labor. Their volume must expand and contract as trading increases or diminishes.

It is not necessary to trace the evolution to gold and silver as tokens superior to all others. They are divisible without loss; they are divisible into all the different values; they are beautiful and brilliant, and durable almost to eternity.

Next as to coinage: The tokens became a standard article and had to be distinctive. In Greece each city claimed the exclusive right to issue these; in the Roman Empire, the privilege belonged to the Emperor; while in France certain nobles said it was their right, and, as with many other things, they seized the right and held it, compelling the people to submit. In England the king alone coined silver and gold, and latterly it has been recognized as the exclusive privilege of the National government.

Every country has a history of the depreciation of its national currency due to various reasons, such as wars, famines, etc. Every currency system must be based on a standard unit of value fixed on some concrete substance. In England the unit of value is the pound, while in France it is the franc, and in America, the dollar. The currency must be suited to the wants of the people using it, or it fails of its intended purpose. The inhabitants of California refused to accept our greenbacks during the Civil War, insisting upon the use of gold; and gold is much more largely used out there now than paper money. Every currency system requires the use of subsidiary coins, which are sometimes made of copper or nickel. Our modern currency has been largely supplemented by the use of credits, checks, drafts and bills of exchange.

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*Lecture delivered before the Schenectady Section, A. I. E. E. January 16.

The Government furnishes various kinds of money with which to carry on business. Some kinds are good enough to use between the business people of the country, but not good enough to suit the Government. It requires a special kind of money when it has a debt against you. If you have duties on imports or interest on the public debt to pay, there are only certain kinds of money the Government will accept; that is, gold coin and silver dollars, or gold certificates and silver certificates, and United States Treasury Notes. The Government is bound, and the Secretary of the Treasury is likewise bound to maintain the parity of gold and silver, no matter what it costs.

United States notes or greenbacks have been redeemable in gold since 1900, and are now in circulation to the amount of $346,681,016. They are legal tender except for duties on imports and interest on the public debt. The Government does not accept any paper in payment of debts, with one exception; namely, the U. S. Treasury notes of 1890, originally amounting to $155,931,000, being the amount paid by the United States for silver bullion. They are legal tender, unless otherwise specified in contracts.

Gold certificates are issued by the Secretary of the Treasury upon deposits of gold coin, the certificates therefor being in denominations of not less than $10.00. These certificates are not legal tender, but are receivable for customs, taxes and all public dues.

Silver certificates are issued for silver dollars deposited with the Treasurer of the United States. These certificates have largely taken the place, in circulation, of the standard silver dollars which they represent. They are not legal tender except for public dues. Then we have the bank notes issued optionally by National banks, which are limited to the face value of bonds deposited in the National treasury, and are redeemable at a central redemption agency in the treasury at Washington. These are legal tender except for duties on imports and for interest on the public debt.

Money Institutions of New York State

I have mentioned the kinds of money the Government furnishes to the people, and this has brought me down to the issue of National bank notes. Before further describing these National banks and the notes issued by them, I would say that moneyed corporations chartered under the laws of the State of New York to do business therein are known as Trust Companies, Saving Banks, Mortgage, Loan and Investment Companies, and Building and Loan Associations. I was accused once of making a financial statement without a figure in it. I was not guilty of quite this, but I want to be as nearly so tonight as possible. The total resources of these institutions amount to $3,398,000,000, with a capital stock of $263,000,000. You can see, therefore, the vast importance of these State corporations. The *State Bank Act* is called in this state "The Banking Law," and seems to have been passed in 1882. It was re-passed in amended form in 1892, and is very much like the so-called National Banking Act.

Each director of a State bank must be a citizen of the United States—not an alien. The liability of a stockholder in the event of impairment of capital is to double the amount of his stock. Every State bank must render a report of its financial condition on approved forms, and at required intervals.

A State bank may be changed to a National bank, and likewise a National bank may be changed to a State bank. Circulating notes are issued on the security of stocks or bonds of the State or United States, which are deposited with the superintendent of banking; and on application the notes, engraved in the proper form, and issued by the banking superintendent, are given to the local bank, and have printed across the face of them, "secured by public stocks." These notes are issued to 90 per cent. of the commercial market value of the securities pledged, and redemption agencies are established in New

York, Albany and Troy. It is not absolutely necessary that a bank should take out any circulation; if it is found convenient, it may be done, or the bank may return the notes to the superintendent, and after a certain interval can require their securities to be reconveyed to them. It will be observed that the primary object of this law was to establish and maintain a system of banking. The act provides for a State banking department, and a bank superintendent with provisions for regular and rigid inspection. There are restrictions as to the amount that can be loaned to any one borrower. They may invest their deposits in municipal bonds, stocks etc.; also in railroad bonds, some of which are specified. The capital stock which must be paid up must be $500,000 in large cities of 500,000 population or more, and as little as $20,000 in small places. A deposit of $1,000 in some municipal stock must be made before a certificate can be issued and business begun. Directors must subscribe to an oath. Reserves of 15 per cent. of deposits must be maintained in large cities, and 10 per cent. in smaller ones, but of this, one-half may be on deposit in another bank on call.

As to trust companies: The difference between a trust company and a bank lies chiefly in the fact that originally trust companies were instituted to execute trusts, to administer the estates of insane persons, to be executors of wills, etc., and to do various other business of a trust character; and incidentally they were allowed, by the peculiar phraseology of the act itself, to receive public deposits. It was never intended that they should enter into the banking field generally and compete with chartered banks for deposits by the people, but by a construction of the statute itself it was found possible to do so, and the intrusion of trust companies as competitors for the business of banking is a comparatively modern development. The capital of a trust company must be $500,000 in cities of 200,000 population.

Trust companies also deal in securities, and receive money on deposit upon which interest is allowed, much the same as in the case of savings banks. They have, however, no right to issue bank bills, as do National banks, and they are not permitted to have branches, except in large cities. They have power to act as safe deposit companies. It was supposed that when they were compelled to invest their capital in bonds and mortgages that it would be an assurance of security to their patrons, but it has turned out that this system was not particularly advantageous. The principal difference between banks and trust companies, as originally intended, was that the trust companies were not required to keep any fixed ratio of reserves against their deposits. Last year, however, this law was changed and in cities of 800,000 population and over, they are now required to keep reserves of 15 per cent. of which one third may be in bonds, and not more than two-thirds may be on deposit in approved banks or trust companies. In smaller cities the reserve must be 10 per cent., of which at least three-tenths must be in money; not more than three-tenths may be in bonds; and not more than four-tenths in approved depositories.

The business or function of a bank, broadly speaking, is to gather up the savings of the people, and to make them useful for the promotion of the business and industries of the country under well-defined banking principles and safe and proper restrictions.

National Banks

We next come to the National banking statute passed in 1864. This National banking act was devised "to provide a National currency secured by pledge of United States bonds, and to provide for the circulation and redemption thereof," and National banks are agencies or institutions of the Government for this purpose. You know something of the circumstances in 1864, when the country's resources were depleted by the War of the Rebellion. The credit of the country had fallen low from the enormous slaughter of the population and the withdrawal of so many men from the industries, etc. The National securities were quoted at extremely low prices, and the country was flooded with irredeemable currency, of which it was said one needed about an equal number of cords to buy as many cords of wood.

The needs of the National treasury were exigent; the expenditure was enormous. There was a great struggle between those who favored the system of a monopoly, and the advocates of absolutely unrestricted freedom for banking; and from time to time the balance had swung from one side to the other. Loan after loan was made; the country was getting more and more deeply into debt. It was Alexander Hamilton who originally suggested the germ or basic principle; to "Bank upon the National debt as the best available capital." The draft of the proposed act was taken bodily from the laws of those states which appeared to have attained the greatest success under the free banking system, and sections covering the features of the securities to be pledged and the methods of supervision were added. Primarily, the aim was to procure the necessary funds for the purposes of the country, and incidentally to put into circulation bills furnished by the government, their redemption to be guaranteed and regulated by the United States. Added thereto was the skillful preparation of the law establishing banks, and the honest enforcement of appropriate banking laws. The following are the principal features of this act establishing these National banking associations — the instruments through which forced loans were to be obtained from the people, the value of the United States Bonds was to be enhanced, and a National currency system put into operation.

Congress has the sole right to regulate and control the operations of the National banks; the State legislatures cannot interfere. The usual powers incident to a banking business are conferred, but loans on the security of real estate are prohibited. In cities of large size (50,000), the capital must be $200,000; in smaller communities, as low as $25,000 is allowed. Of this 50% must be paid up, and the balance in monthly installments of 10%.

Directors must subscribe to an oath and must be citizens of the United States; furthermore three-fourths must have resided in the state at least one year, must be residents therein during continuance of office, and must qualify with 10 shares of stock. Shareholders are liable to double the amount of their stock in case of impairment of capital, except where the capital is as large as $5,000,000 and surplus of 20 per cent. Executors or trustee stockholders are not personally liable to assessment, but the estates they represent are.

These National banks are constituted depositories of public monies except customs receipts. They may be employed as financial agents of the government, and the secretary of the treasury may require them to give satisfactory security for deposits, etc. They must take and receive at par all the National currency bills which have been paid into the Government for interest, revenue, or for loans or stocks. Any State bank may become a National bank.

Obtaining and Circulating Notes

Before it can begin business, each National bank must deliver to the treasurer of the United States at least $30,000 of United States bonds and not less than one-third of its capital stock paid in; and this proportion of 30 per cent. must be maintained when the capital is increased. These bonds are held in trust for the bank and as security for circulating notes; the controller of the currency and the United States treasury act together. Banks whose capital is $150,000 or less, need not deposit bonds of over 25 per cent. of their capital. A bank can deposit lawful money and withdraw a proportionate amount of bonds. Circulating notes are delivered to the bank equal to the par value of the bonds deposited, but not in excess of its capital paid in. In order to keep these notes in circulation it was originally provided that if they were presented for redemption, the bank could not increase its circulation again for six months, but for obvious reasons this section was repealed. It was for the same purpose, however, that the law provides that the secretary of the treasury cannot be compelled to redeem more than $9,000,000 circulating notes in any one month and "first come, first served." It is this feature of rigidity that is found so objectionable in practical operation. Each man and each business enterprise requires enough money for purposes of exchange, and, at certain seasons of the year more currency is needed than at others. The moving of the crops in the autumn necessarily employs a large volume of circulation, and it seems absurd that the business of the country generally should be disturbed, and the value of money should be enhanced to borrowers all over the country while this beneficent work is being accomplished. As stated at the outset, a proper currency system should be adequate in amount for all purposes, and should automatically expand and contract as the need for it arises and ceases. There should be a daily system of redemption going on, so that there should neither be too little nor too much. This element of elasticity is one great defect in our bond secured currency, and it is clear that the act was never designed to furnish this needed flexibility.

(To be continued)

ROTARY CONVERTERS

PART III

BY E. J. BERG

Ratio of Copper Losses

They show, also, that the ratio α of the armature copper losses of a given machine, when run as rotary converter and direct current generator, is as follows:

$m = 2,\ \alpha = 1.42$
$m = 3,\ \alpha = 0.57$
$m = 4,\ \alpha = 0.377$
$m = 6,\ \alpha = 0.266$

The relation between the total armature heating of a converter at any power factor, and the machine as a direct current generator, is as follows:

Let i be the effective value of current corresponding to the energy output, and let cos ϕ be the power factor; thus, with full energy output, the wattless leading or lagging component of the current is $i_a \tan\phi$.

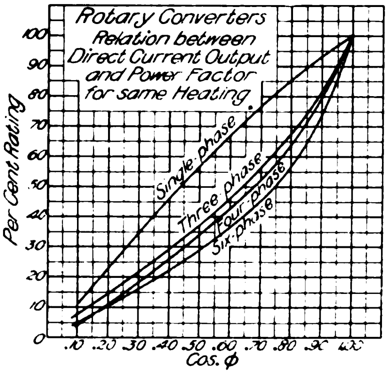


Fig. 1

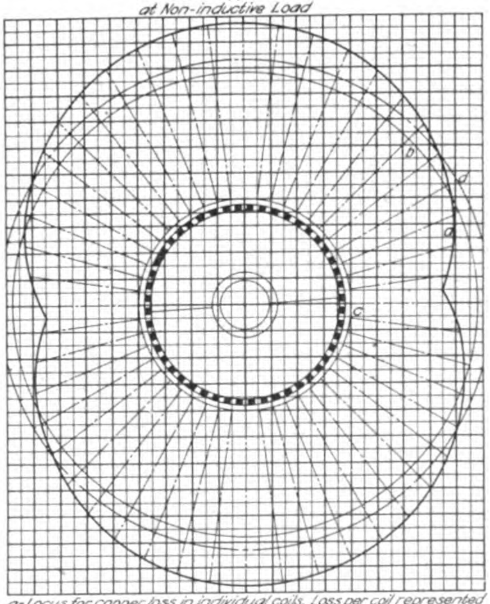
With inductive load, the armature copper losses are increased in the proportion of the square of the wattless component to the square of the resultant energy component previously discussed.

Copper Losses at Different Power Factors

The effect of the wattless component is, however, not a uniform addition of losses all around the circumference. The coils near the collector rings carry relatively more current than with non-inductive load; thus the distribution of heat with wattless current is less favorable than with non-inductive current. This distribution is, however, improved with an increased number of phases.

It has been previously shown that the ratio between the effective value of the alternating current in the armature and the direct current, is:

Single-phase Double Current Generator
Armature Copper Losses
at Non-inductive Load



a=Locus for copper loss in individual coils. Loss per coil represented by radius vector measured between "c" and "a".
Area between "c" and "d" represents total heating.
Area between "c" and "a" represents D.C. heating same output.

Fig. 2

$$\frac{2\sqrt{2}}{m\sin\frac{180}{m}}$$

Thus the wattless current, expressed as a function of the direct current, is:

$$\frac{2\sqrt{2}}{m\sin\frac{180}{m}}\tan\phi$$

and the heating due to this current, as a percentage of that obtained with direct current, is:

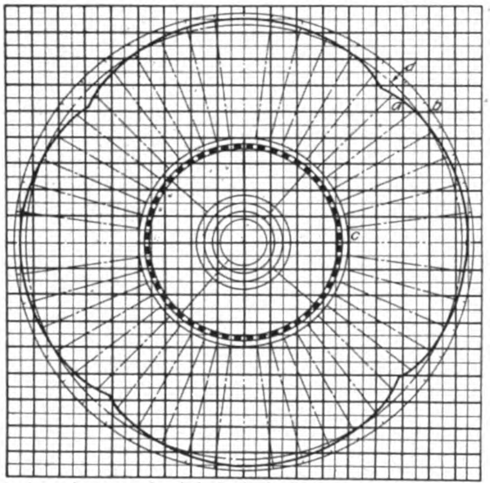
$$\frac{8\tan^2\phi}{m^2\sin^2\frac{180}{m}}$$

At a power factor cos ϕ, the heating as a percentage of the direct current heating, is, therefore:

$$100\left(0.57+\frac{8\tan^2\phi}{m^2\sin^2\frac{180}{m}}\right)$$

Where the value of a is obtained from the above table—for instance, in the case of a three-phase converter operating at 90 per cent. power factor ($\cos\phi=0.90$), we have:

Two-phase Double Current Generator
Armature Copper Losses
at Non-inductive Load



a-Locus for copper loss in individual coils. Loss per coil represented by radius vector measured between "c" and "a"
Area between "c" and "d" represents total heating.
Area between "c" and "b" represents D.C. heating same output.

Fig. 3

Percentage heating =

$$100\ \left(0.57+\frac{8\times0.484^2}{9\times0.866^2}\right)=83.4 \text{ per cent.}$$

For a six-phase converter the corresponding heating is:

$$100\left(0.266+\frac{8\times0.484^2}{36\times0.25}\right)=47.4 \text{ per cent.}$$

The power factor which will give the same armature copper loss as that with direct current is found by the following equation:

$$a+\frac{8\tan^2\phi}{m^2\sin^2\frac{180}{m}}=1$$

$$\tan\phi=.354\,m\sqrt{1-a}\,\sin\frac{180}{m}$$

Tan ϕ being known, cos ϕ, the power factor, is directly obtained from trigonometric tables.

Example: Find the power factor for a six-phase rotary converter which will give the same armature copper loss as direct current only.

$$\tan\phi=0.354\times6\times\sqrt{1-0.266}$$
$$\cos 60^\circ=0.905$$
$$\text{thus}\ \cos\phi=0.743$$

Example: How much shou'd the rating of a three-phase rotary converter be reduced for a power factor of 90 per cent.?

We then have:

$$a=0.555$$
$$\cos\phi=0.9 \qquad \phi=25.5^\circ$$
$$\tan\phi=0.474 \qquad \tan^2\phi=0.225$$

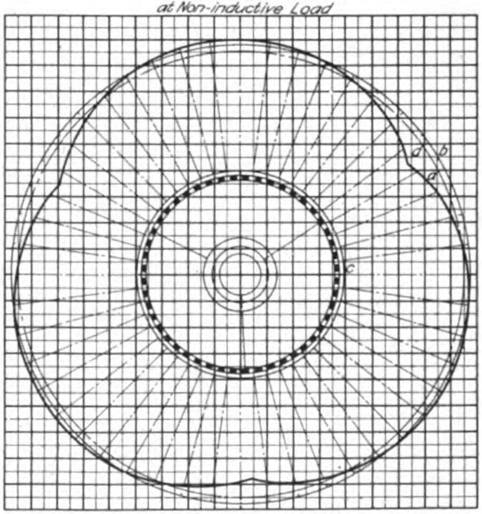
Substituting:

$$C_c=\sqrt{\frac{0.555}{0.555+\frac{8\times0.225}{9\times0.75}}}=0.82$$

Thus the output should be reduced to 82 per cent. of the rating.

In a rotary converter it is of importance to know how much lower the direct current output will be when the power factor of the alternating current is not unity. To illustrate the method of determining this, let the direct current i_c in the winding at full load be 1; the alternating current (see equation 4) in the winding is then:

Three-phase Double Current Generator
Armature Copper Losses
at Non-inductive Load



a-Locus for copper loss in individual coils. Loss per coil represented by radius vector measured between "c" and "a."
Area between "c" and "d" represents total heating.
Area between "c" and "b" represents D.C. heating same output.

Fig. 4

$$i=\frac{2\sqrt{2}}{m\sin\frac{180}{m}}$$

and the heating due to these currents is a.

With a direct current in the winding of C_c, the alternating current in the winding,

$$C = \frac{2\sqrt{2}}{m \sin \frac{180}{m}} C_c;$$

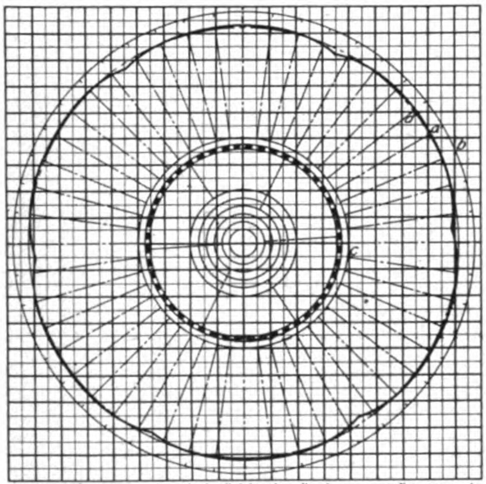
and the heating of the machine as a converter is $C^2 a$.

At a power factor of cos ϕ the wattless component of the alternating current in the winding is:

$$C \tan \phi = \frac{2\sqrt{2}\, C_c \tan \phi}{m \sin \frac{180}{m}}.$$

Thus the heating, due to the current which is not compensated for, is proportional to:

$$\left(\frac{2\sqrt{2}\, C_c \tan \phi}{m \sin \frac{180}{m}} \right)^2$$



Six-phase Double Current Generator Armature Copper Losses at Non-inductive Load

a-Locus for copper loss in individual coils. Loss per coil represented by radius vector measured between "c" and "a".
Area between "c" and "d" represents total heating.
Area between "c" and "b" represents D.C. heating same output.

Fig. 5

Thus the total heating is proportional to:

$$C_c^2 a + \frac{8C_c^2 \tan^2 \phi}{m^2 \sin^2 \frac{180}{m}}$$

This value should be the same as for rated load, thus:

$$C_c^2 a + \frac{8C_c^2 \tan^2 \phi}{m^2 \sin^2 \frac{180}{m}} = a$$

$$\text{and } C_c = \sqrt{\frac{a}{a + \frac{8 \tan^2 \phi}{m^2 \sin^2 \frac{180}{m}}}}$$

Since these values are of very great practical importance, Fig. 9 has been prepared, which shows these relations for the various types of rotary converters.

The interesting characteristics of the various types of rotary converters are tabulated below, where:

A gives type of converter.
B " power factor.
C " ratio, $\frac{\text{A.C.}}{\text{D.C.}}$ no-load voltage.
D " ratio, $\frac{\text{A.C.}}{\text{D.C.}}$ line current.
E " ratio, $\frac{\text{maximum value A.C. current}}{\text{direct current}}$
F " ratio armature copper loss as rotary and D.C. generator for same output.
G " ratio of rating as rotary and D.C. generator for same armature copper loss.
H " power factor for same energy output and copper loss as rotary and D.C. generator.
M " number of collector rings.

A	Single-phase		Three-phase		Four-phase		Six-phase	
B	100	90	100	90	100	90	100	90
C	.707		.613		.5		.353	
D	1.414	1.57	.945	1.05	.707	.785	.472	.525
E	2	2.22	1.54	1.71	1.414	1.57	1.333	1.48
F	1.43	1.88	.555	.82	.377	.60	.26	.46
G	.84	.73	1.34	1.11	1.63	1.29	1.94	1.47
H	....		85		78.5		74	
M	2		3		4		6	

Figs. 10, 11, 12 and 13 give diagrammatically the distribution of armature losses in single-phase, three-phase, two-phase and six-phase double current generators. These diagrams are calculated in a similar manner to those for the rotary converter. Instead of the alternating current being $+ i_{max}$ in the first position, it is $-i_{max}$ and the direct current and alternating current are thus in phase.

It is of interest to note that, with the same output on the direct current and alternating current side, the actual armature copper loss in all but the single-phase case, is less than if all output was given as direct current, the relative ratings being:

Six-phase machine	106.8 per cent.
Four-phase machine	105. " "
Three-phase machine	102.5 " "
Single-phase machine	93. " "

(*To be continued*)

WOOD MANTELS PRODUCED BY ELECTRICAL POWER

By John P. Judge

The Felippe A. Broadbent Mantel Company of Baltimore, Md., operated their factory for several years previous to 1904 with mechanical drive. During that year they built an entirely new factory, and after considerable investigation, determined to have all of the woodworking tools driven separately by electric motors. The new equipment was started on January 1, 1905, and therefore has now been in operation for more than two and one-half years. The fact that the owners are pleased with the results obtained is well shown by the accompanying letter.

"We take pleasure in stating that we are more than satisfied with our electric equipment in every way; the writer having in person examined a number of woodworking plants (some of which were the largest in the world) and is confident that we have the most perfect electrically-equipped woodworking plant in this country.

"Certainly, anyone seeing this plant, who knows anything about the equipping of woodworking machinery, could not help but state that it is almost as near perfect as it could be made; the application of the electrical equipment to the machines being such as to almost entirely do away with belting, thus saving us great expense in the constant stopping of the machines to take up belts, etc. We are particularly well pleased with the equipment of the turning lathes, which does away with the belts entirely. The doing away with these and the pulleys we find particularly advantageous, as it eliminates the collection of dirt on the latter, which was constantly dropping on the work. The belts were always in the way.

"I had, of course, considerable apprehension as to the delays we might suffer in running the plant electrically equipped, until the same was in thorough working order, but I must say that this apprehension was entirely uncalled for; for, though the men had never run machines of this kind before, we have had very little trouble, and only a few slight delays since we have started.

* * * *

"We do not believe the lighting could be improved upon, and the men in some cases prefer it to the daylight.

* * * *

"Were we to build another plant, certainly nothing would be used but electricity. The economy, of course, is very great, as the power is entirely saved whenever the machines are not in use, and it is really astonishing to know the difference between the horse-power in motors, and the horse-power which is being consumed.

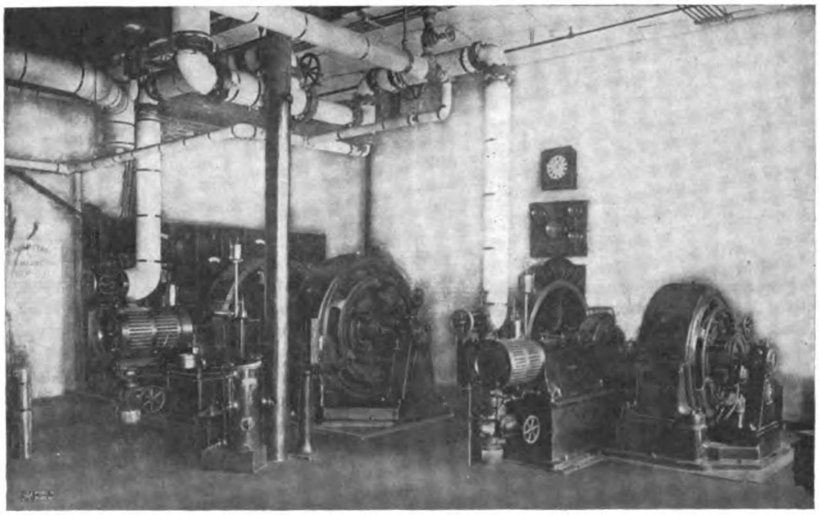


Fig. 1. Interior of Power House. Felippe A. Broadbent Mantel Company

"After running two years and a half, we find we have spent less than $200.00 in repairs for electric equipment."

* * * *

(Signed)
Yours very truly,
Felippe A. Broadbent Mantle Co.,
F. A. Broadbent, Pres.

The factory is located in a low part of the city, near the harbor, and in that section basements are usually avoided, because of trouble from tide water.

Before the system for driving had been determined upon, the architect had prepared his plans, and the building was about ready for the roof. A careful consideration of the matter impressed the owners with the advantages to be gained by having the motors for the heavy machines placed in a basement. Fortunately, the first floor had been laid out for a 22 foot pitch; this was cut down to 17 feet, and by digging down about 3 feet further a basement was secured 7 feet high, in which all of the motors for driving the heavy machines on the first floor could be located. This permitted standard motors, without covers or artificial ventilation, to be used. Although a considerable expense was incurred, the owners are well satisfied with the results, and feel assured that the money involved was well invested.

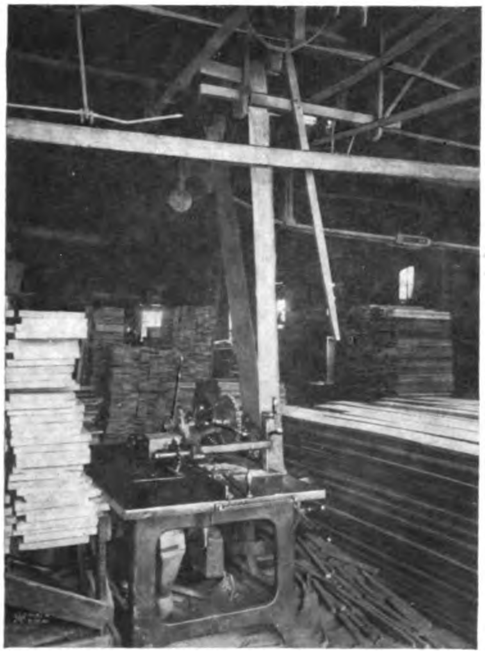


Fig. 2. Automatic Rip Saw, Belt Driven

The generating plant consists of two engine-type generators, rated:

MP-6-100 kw.-270 r.p.m.-250 volts,
MP-6- 50 kw.-280 r.p.m.-250 volts

each mounted on the base of a horizontal engine, running non-condensing.

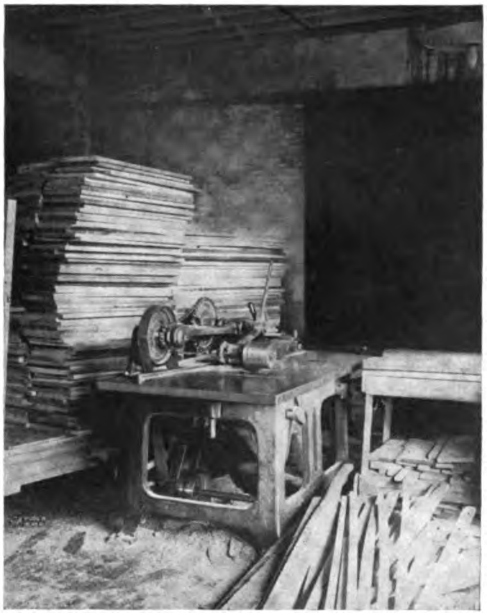


Fig. 3. Automatic Rip Saw Driven by 15 h.p. Constant Speed Motor Located in Basement

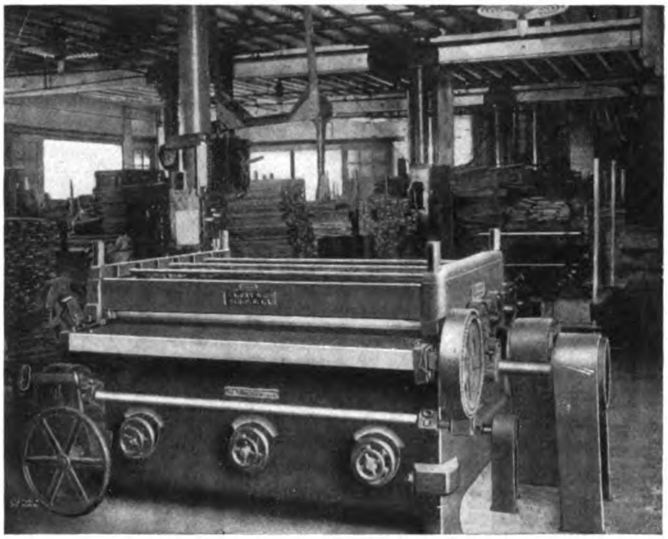
The switchboard consists of seven black enameled slate panels with instruments, including among the latter a recording wattmeter for each generator panel.

In this installation the owners acted along broad lines, with the fundamental intention of securing a maximum of output with a minimum of cost, and to obtain a motive power free from delays and interruptions, due to break-downs and improper attention.

Forty-five motors, aggregating 398 h.p., are installed, all of them being 230 volt, continuous current machines.

A characteristic of many woodworking machines is that the speed of the cutting tool remains constant, while the feed should be varied in accordance with the work being done. This applies especially to sanders, planers, jointers, and machines of this class. These machines were fitted with a constant speed motor for the cutting tools, and a variable speed motor-controller for the feed, and the results have been most satisfactory.

The old method involved the use of considerable shafting and belting with cone pulleys, giving only a few feed speeds, while with the variable speed motor a much greater range of feed speed can be obtained, with more gradual increments, resulting in better work, greater production and less wear and tear. This is especially noticeable in the large sanders.



60" Triple Drum Power Feed Sander Driven by 25 h. p. Motor Direct Coupled to Counter Shaft, which is Located in Basement Below the Machine

There is no overhead belting on the first floor, and in fact, very little on any of the floors. On a number of the large machines having several working cylinders, it is necessary to use one belt to each cylinder, but even with these machines there is a striking difference between the old and new systems.

Many of the machines now in use were employed in the old shop, while others were designed especially for electrical driving. For large machines requiring several belts, the main motor is coupled directly to the counter shaft, while the feed motor is belted to the feed shaft.

Under the old system, the large automatic lathe for turning up columns required an elaborate installation of counter shafts and belts, with tight and loose pulleys. This lathe is now belted direct to a motor overhead, and is giving much better service and a materially increased output.

Each of the swing saws is operated by a 3 h.p. motor, mounted in the arbor of the saw. We found very little difficulty in mounting these motors, even in the saws moved from the old factory.

The double end sander was another machine taking up a large amount of room, because

60" Triple Drum Power Feed Sander—Belt Driven

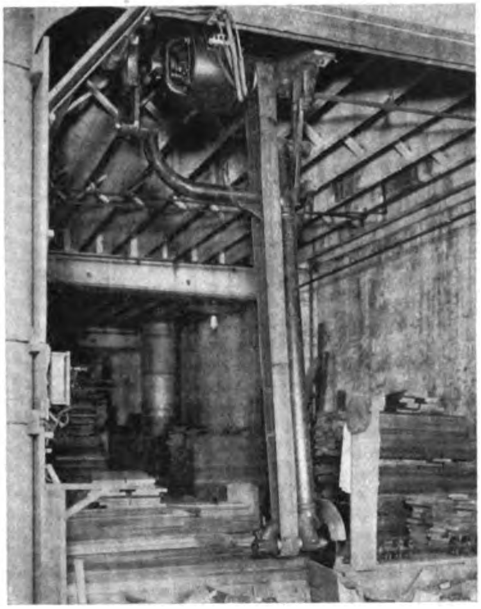


Fig. 6. Motor Driven Swing Saw

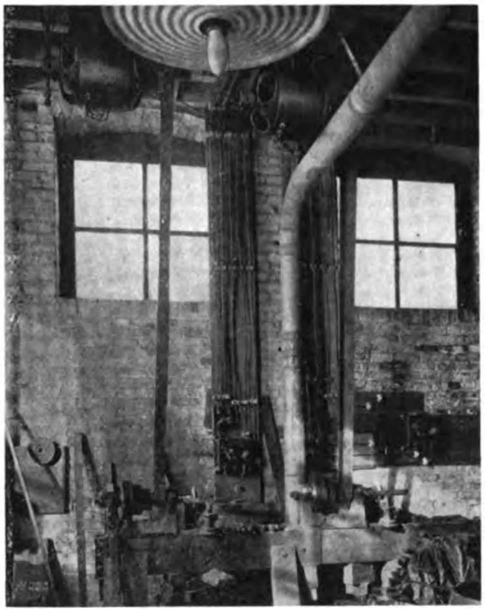


Fig. 7. Motor Driven Bench Lathes

it was necessary to use a counter shaft and three belts. The new equipment consists of two motors, each carrying a disc 30 in. in diameter, with external shafting or belting.

Perhaps the greatest simplicity was secured in a number of small lathes used for sandpapering, filling, veneering, etc. On each of these the motor takes the place of the head

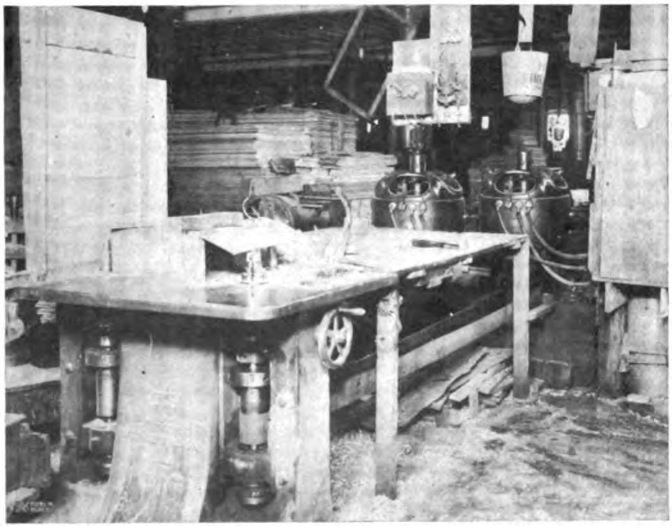


Fig. 8. Variety Molder—Driven by Two 5 h.p. Motors with Vertical Shafts

stock, and is furnished with a standard shaft, the end of which is threaded for such chucks or discs as the owners may require, and which are supplied by them.

The putty mixer is an adaptation of the standard J. H. Day, three-barrel dough mixer, and is used for mixing compositions consisting principally of whiting and glue. An ordinary batch consists of one barrel of whiting, with the proper quantities of glue and other materials, and the actual mixing requires only about 5 minutes. Mixing the compositions by hand, under the old system, required an hour and a half for this work. The owners say the product as now obtained from the electrically driven machine is much better than formerly, the materials being more thoroughly mixed, and require less time to dry; this latter item being one of considerable importance.

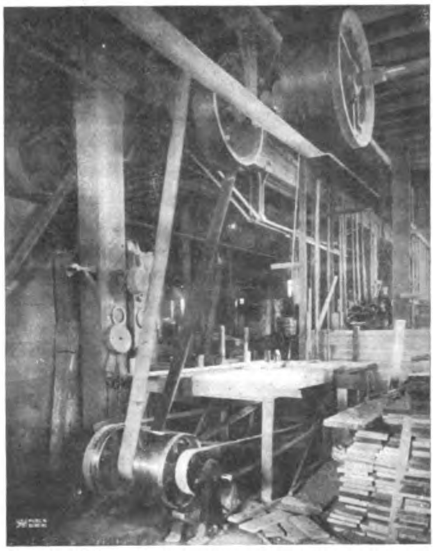


Fig. 9. Variety Molder Belt Driven.

Of the total motor rating of 398 h.p., the shaving blowers, which run constantly, require 95 h.p. The average load is about 150 kw., but for short periods it goes up to 200 kw., with momentary jumps as high as 225 kw.

Eliminating the blowers, the load factor on the woodworking tools varies from 30 to 35 per cent.

The entire mill is lighted with General Electric multiple D.C. 110 volt arc lamps, with concentric diffusers, run two in series, on a 250 volt circuit.

SOME NOTES ON WIRING AND WIRING SUPPLIES FOR MINING SERVICE.

By F. A. Barron.

Part II

In many coal mines it is customary, for underground illumination, to use incandescent lamps only in the mine shaft, in approaches to the foot of the shaft, at track switches, and for visual signalling; relying on the headlights of the locomotives and the miner's lamps for illumination in other parts of the mines. Miners have become so accustomed to working by the dull glare of their head lamps, that even where conditions are favorable and power is available for general lighting of the gangway and chambers, they appear quite indifferent to better illumination. The method of supporting the lighting circuits along the gangways, air ways, walls and roofs, to their destination, is by porcelain or glass insulators mounted on wooden cleats; and the same care and precautions are exerted here as in exposed circuit wiring in wet places, except that owing to the presence of sulphuric acid in the moisture and water of the mines, bare wires are frequently used in preference to insulated ones. The feeders for trolley wires and pump motors, where exposed to mechanical injury, are usually encased in iron conduit.

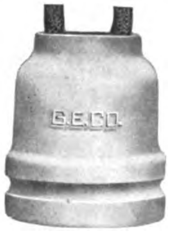


Fig. 1. Weatherproof Lamp Socket.

The lamp sockets used in mines are usually of the 125 volt keyless weatherproof type, made of porcelain, or mica and hard rubber compounds. The latter will stand more hard usage, as they are tougher and less brittle than the porcelain, and are therefore more generally used in places where the sockets are exposed to injury. These sockets are provided with leads for connecting them directly to the circuit wires, allowing the lamp to hang suspended, and enabling it to swing if struck. These sockets are shown in Fig. 1.

Where lamps are mounted rigidly to side walls, they are usually attached to receptacles which are similar to those shown in Fig. 2.

Where portable lamps are required, they are frequently connected to the circuit by heavily insulated flexible cord, and are protected by an extra heavy steel ribbon lamp guard, like that shown in Fig. 3.

In the largest mining plants, the power required for illumination above and below ground rarely exceeds 20 to 25 kw., and most of this is used above ground in the power station, coal breakers, washeries, and other buildings. The wires in the coal breakers and washeries are now required to be run in iron conduits in the most approved manner, and controlled from distribution panels where each circuit has its individual devices for protection. On account of the accumulation of coal dust in the breakers, and moisture in the washers, all protective devices must be enclosed in cabinets; and keyless weatherproof sockets, suspended by reinforced lamp cord, must be used. The mine inspector insists that all wiring be maintained in such a condition that absolute reliability and immunity from even a temporary interruption to the service is secured.

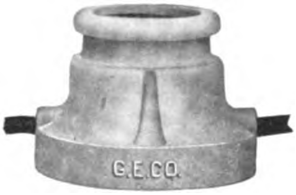


Fig. 2. Wall Lamp Socket

Where alternating current motors are used, they are provided with individual controlling panels as shown in Fig. 4. These panels are designed by the General Electric Company for motors of from 25 to 450 h.p., for voltages up to 2080 volts, and are made of blue Vermont marble, 28 in. high, 16 in. wide, and 1½ in. thick, mounted on pipe frame supports, and attached to the pipes by malleable iron clamps. The total height of the panel and of the supports are 64 and 72 in., respectively. The 72 in. supports provide the space necessary for mounting the compensator, when this is used for starting the motor. These panels are usually mounted as near to the motor as conditions will permit, and are equipped with an ammeter and oil switch, the latter designed to automatically open the circuit in case of overload or trouble on the line. When controlling motors of moderate size, the wiring to and from these panels consists of multiple conductor lead armored cable, protected by metal conduits. Where motors of large capacity are used, three separate lead armored cables are enclosed in a single iron conduit, the latter in each case being connected to ground.

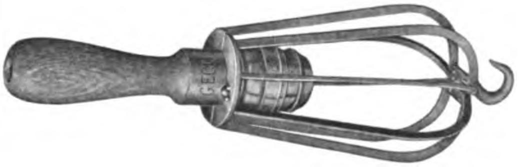


Fig. 3. Lamp Guard

The trolley wires used for mining locomotives vary in size, depending upon the particular haulage problem under consideration, and many features found desirable in trolley wire construction for passenger transportation are often taken advantage of in mining haulage. The grooved trolley wire possesses some advantages over the round type in that it provides a groove into which the ear may be securely clamped, making a neater job than a soldered construction, with less obstruction to the passage of the trolley wheel, and at the same time avoiding the ill effects of heating the wire necessary in the operation of soldering. The clamped ear may be readily removed when a change of location is to be made, and is interchangeable on Nos. 00, 000 and 0000 wires. The grooved trolley wire permits a larger cross section of copper without increasing the diameter of the contact surface. A diagram showing how the clamping ear holds the grooved trolley wire is shown in Fig. 5.

The underground trolley wires are suspended from either the roof or side walls of the gangways, the choice depending upon the nature and material of the roof and walls, and upon which is the more secure and convenient.

The following is an approximate estimate of the cost of 1,000 ft. of trolley construction in coal mines, including rail bonds:

36 single bolt roof suspensions	$15.00
30 straight ears for grooved wire, GE Cat. No. 19432	6.00
6 curved ears for grooved wire, GE Cat. No. 19433	
1000 ft. of 0000 grooved trolley wire (641 lb.)	94.00
210 ft. of 00 bond wire (85 lb.)	12.00
175 ft. channel pins, GE Cat. No. 17315	5.00
Labor and other material	50.00
Additional labor, if necessary, to drill rails for bonds with a hand drill	15.00
Total cost per 1,000 ft	$197.00

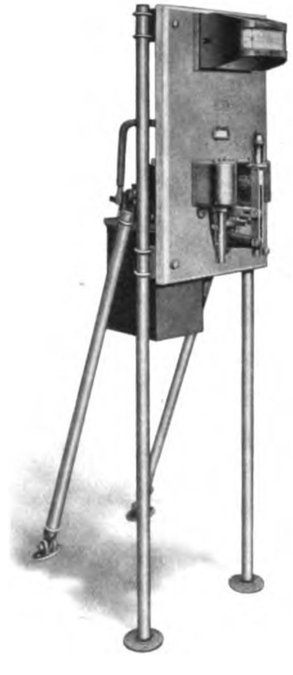


Fig. 4. Alternating Current Motor Panel on Pipe

Other sizes of trolley and bond wires may be readily substituted in the above estimate.

The constructional details of electric circuit wiring in subterranean workings of coal mines have, in common with electric wiring in other fields, very much improved in recent years, although the predominating blackness, and the wet, rough, and rugged surroundings are not an incentive to the ordinary electrician to attempt a neat and symmetrical job of wiring.

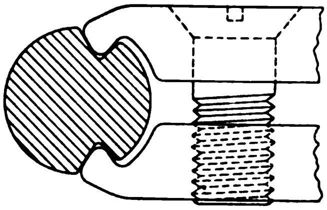


Fig. 5. Suspension for Grooved Trolley Wire

The essentials of every department of mining service—utility, safety, and a rugged simplicity—are usually the guiding considerations in running electric circuits in coal mines.

The United States government in its effort to protect the miners from the gases of the mines, has placed certain restrictions on the use of the miners open lamp in mines where gas is emitted in such quantities as to be detected in the presence of an open flame. In the anthracite coal region of Pennsylvania there are mines which, a few years ago, were considered as non-gaseous, but which, in the extensions of recent years, have shown such an increase in the quantity of gas emitted as to come within the restrictive measure framed by the government for gaseous mines. In the discussions that have arisen in the enforcement of the use of locked safety lamps and the restrictions to the further extension of electric circuits in the working sections of these mines, the miners have in many cases agreed with the operators that the open lamp is safer than the safety lamp, since the open lamp enforces a better ventilation, while with the use of the locked safety lamp, ventilation may be considered as not so essential.

CHARACTERISTICS OF ELECTRIC MOTORS*

How the Work to be Done Determines a Motor's Continuous and Intermittent Capacity and Its Design and Rating

By Edwin H. Anderson

To perform a given amount of continuous work, the motor should be designed both electrically and mechanically for continuous duty, and rated on the continuous basis. Let us suppose that the work is driving a machine requiring 50 horse-power continuously, there being no variation in the load. The motor for this purpose should have a constant speed, capable of delivering 50 horse-power continuously, with a temperature rise which will not injure the materials with which it is insulated, when operating under conditions of proper speed, voltage and ventilation.

Let us suppose the work consists of 50 horse-power for five minutes and 10 horse-power for 10 minutes; the cycle to be repeated every 15 minutes and the speed to be constant. The speed characteristics of the motor require a shunt excitation, that is, a definite exciting current in the field regardless of the load in the armature. The average load of the motor is:

50 × 5 minutes = 250 horse-power minutes
10 × 10 minutes = 100 horse-power minutes

Total.......... 350 horse-power minutes

$$\frac{350}{15} = 23.3 \text{ horse-power average.}$$

This average load will not produce the heating that the cycle will, for the reason that the copper loss varies as a square of the current. The root mean square or equivalent heating will be produced by the following:

50^2 × 5 minutes = 12,500 h.p. square minutes
10^2 × 10 minutes = 1,000 h.p. square minutes

Total.......... 13,500 h.p. square minutes

By dividing this over 15 minutes, we get the average square as 900, which is 30 horse-power. This is the root mean square load or a load which will produce the same heating, if applied continuously, as would the intermittent work.

Again, suppose the work is neither constant nor entirely intermittent. The motor must be designed with reference to both, and rated at a certain value continuously and a certain higher load for a given time. The specification of a motor for the intermittent work noted above would be one capable of delivering 30 horse-power continuously with normal temperature rise, and 50 horse-power as a maximum intermittent load. If the work to be done is the same as given above, except at 50 horse-power, the revolutions per minute of the armature should be 500; if at 10 horse-power the revolutions per minute should be 750, and, should the load be thrown off and the motor allowed to run free with full voltage applied, the speed must not be over 1000 revolutions per minute. The motor must therefore be able to deliver 30 horse-power continuously as before, have a shunt winding on the field to give a definite and sufficient field strength so that the speed will not be greater than 1000 revolutions per minute, have sufficient series-field turns so that when taking 10 horse-power of current the field will have sufficient excitation to cause the speed to be 750 and, when taking 50 horse-power of current, will further magnetize the fields so as to produce a speed of 500 revolutions per minute.

If we suppose the work required to be 50 horse-power for five minutes at 500 revolutions per minute and 10 horse-power for 10 minutes at 1000 revolutions per minute, there being no time in which the motor runs without load the field may be entirely series and adjusted properly for the respective loads. The continuous capacity will still be 30 horse-power as before, may be so rated, and have an intermittent capacity of 50 horse-power.

Street Railway Motors

Should the work be that required of railway motors under ordinary street railway conditions, there being no continuous load but a series of intermittent loads, the natural rating is the normal maximum intermittent load for which the motor is designed, both electrically and mechanically. By common usage this rating has become the horse-power output at the car axle which the motor will carry for one hour and not have a rise in temperature, as measured by thermometer, greater than 75 degrees Centigrade. The motor is started cold and run on the stand. The starting or pulling effect at the rating is usually the starting effect used in accelerating the car.

A motor of the usual direct-current series type may be looked upon as one which will deliver continuously about one-third of its hourly rating, or its hourly rating for one-third of the time, the cycle of operation being limited to, say, 10 or 15 minutes. The series characteristic which gives the high speed at light loads and low speed at heavy loads is ideal for street railway work.

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* Reprinted from the American Machinist, Vol. 30, No. 50

The intermittent loads of operating a car may be represented by the following table:

50 horse-power for 10 seconds, accelerating
40 horse-power for 2 seconds
30 horse-power for 6 seconds
20 horse-power for 20 seconds
15 horse-power for 60 seconds
No horse-power for 20 seconds, applying brakes
No horse-power for 10 seconds, stopped
128 seconds per cycle

The average horse-power output is as follows:

50 × 10 = 500
40 × 2 = 80
30 × 6 = 180
20 × 20 = 400
15 × 60 = 900
Total = 2060 horse-power seconds.

The average horse-power over the whole cycle is, therefore,

$$\frac{2060}{128} = 16.1 \text{ horse-power.}$$

The current, corresponding to the horse-power which will produce the same copper loss as in the above cycle, will be the root mean square as follows:

$50^2 \times 10 = 2.500$
$40^2 \times 2 = 3,200$
$30^2 \times 6 = 5,400$
$20^2 \times 20 = 8,000$
$15^2 \times 60 = 15,500$
Total = 34,600

The root mean square for 128 seconds is therefore 21.1 horse-power. The motor has been working on a voltage and current for 98 seconds out of the 128, or 75 per cent. of the time. The continuous capacity then may be approximately a current which corresponds to 21.1 horse-power (root mean square) based upon full voltage and an applied voltage which is 75 per cent. of the normal. This is approximate and not to be relied upon for accuracy. The method, however, serves to illustrate that there is a continuous current and voltage which could be applied to produce the losses and temperature rise of the motors in service. This continuous capacity, however, does not serve to test the motor on its full intermittent capacity at full voltage and, as stated before, it has become general to rate the railway motor on its intermittent capacity of 50 horse-power. The electrical and mechanical design is made with reference to the intermittent rating.

Characteristic Curves

Fig. 1 shows the characteristic curves of the usual direct-current series motor, such as used on street cars, hoists, cranes, and for intermittent work generally. The applied voltage across the motor is 500. The values of speed in revolutions per minute, efficiency, torque at one-foot radius and horse-power output at the armature shaft are shown as ordinates and plotted to amperes input to the motor as abscissas. It will be noted that the curves show the values in the accompanying table.

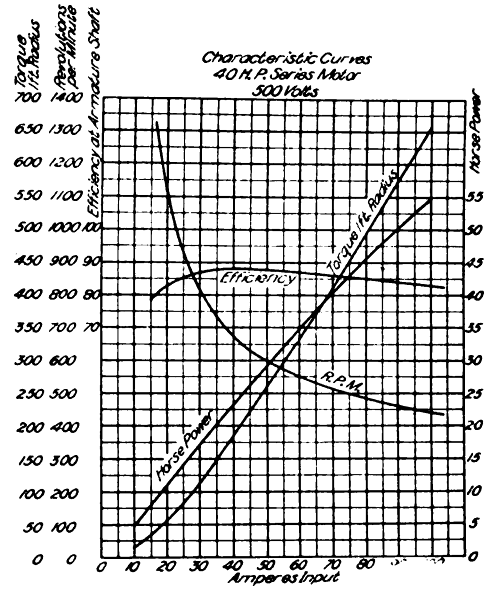


Fig. 1.

Amperes	Efficiency	Speed	Torque	H.P.
100	83	440	660	54.7
80	85	485	493	45.5
60	87	550	334	34.7
50	88	595	258	29.3
40	88	675	185	23.4
30	87	810	110	17.4
25	85	925	80	14.5
20	83	1100	55	10.8
15	78	1400	32	7.6

The measure of magnetizing force is ampere turns. Ampere turns is the product of amperes by the number of turns of wire around each field pole. When the magnetizing force is great, the strength of the magnetic pole is great, and *vice versa*. The applied pressure or voltage across the motor is resisted by two counter-pressures; first, that consumed in forcing the current over the copper wires, similar to friction in water pipes; second, a counter-voltage generated by the armature winding revolving in the magnetic field. This counter-voltage is proportional to the product of armature speed and the strength of the magnetic field. The torque at the armature shaft is proportional to the product of the armature turns, amperes and the strength of the magnetic field.

Should the motor be running at full load and delivering the torque at its armature and this torque be reduced, the motor will increase in speed, raising the counter-voltage and allowing less voltage to be consumed in driving the current through the windings. The current therefore is decreased. The decreasing of the current decreases the magnetizing force of the poles and in turn the strength of the magnetic field; this in turn requires the armature to run at a higher speed in order to generate the counter-voltage; thus the speed at large current input is slow and light current high, producing what is known as a series speed characteristic. With decreased field strength and current, the torque is reduced in proportion to the product of both. The motor almost instantly adjusts itself to the torque required.

We will assume 500 volts applied and 50 volts used in driving a given current through the winding. The counter-voltage produced by the armature revolving in the magnetic field would then be 450. We will now assume 250 volts applied for the same given current as above; thus 50 volts will be consumed in pushing the current through the windings and the counter-voltage produced by the armature will only be 200. Thus the speed at the lower voltage will be in a ratio of 200:450. Should we now assume only 50 volts impressed on the motor, this will all be consumed in pushing the given current through the winding and no counter-voltage will be required. The motor will therefore not run but stand and deliver the same torque as it did under speeds with 250 and 500 volts applied.

The above, while elementary in a way, serves to show that the torque is practically constant for given amperes at various speeds corresponding to various applied voltages and, furthermore, serves to show how the speed of a series motor is affected by the application of various currents and voltages. To perform other work more intermittent than the railway motors, the rating would naturally be on the intermittent basis for a shorter time say three-fourths or one-half hour, or in very intermittent work, such as lift or drawbridges, the rating may be on a 15-minute basis.

Any design must be made with special reference, both mechanically and electrically, to the maximum requirements, as well as to the continuous requirements, should there be any. Should the duty be continuous, the losses in the motor should be properly proportioned between the copper and the iron. The copper loss increases as the square of the current input to the motor, while the iron losses remain practically constant. Should the motor be designed for continuous operation and be operated on an intermittent overload, the copper loss becomes quite high and a better and cooler operating motor for intermittent work might have been made for the same weight and cost. In order to decrease the resistance of the copper circuit, a greater amount of steel may be used. This, however, naturally increases the iron losses but allows a lower copper loss for the same overload. In other words, a motor designed for intermittent work is considerably better than the motor designed for continuous load. A continuous-load motor has usually a small amount of iron with many turns of copper. The intermittent load motor has a large amount of iron with few turns of large copper.

The preceding explanation of the design and rating of motors is given so that the user of motors may appreciate that the character of the work to be performed shall control the design; that motors designed for continuous duty are not well adapted for intermittent work and that motors designed for intermittent work are not well suited for continuous load.

Crane Motors

We will next consider the crane motor. The weight to be lifted requires at the speed an output of 50 horse-power at the armature shaft. The distance to be lifted is, say, 30 feet at 3 feet per second. The time is then 10 seconds with load. The crane is moved down the shop and the weight lowered by a very slight use of the motor. The crane is then run back and the cycle repeated every 100 seconds. The power is on 10 per cent. of the time, and the average load is 5 horse-power. The root mean square load, however, is 15.7 horse-power. The time that the voltage is applied is 10 per cent.; thus the average load, or the root mean square load at 10 per cent. of the normal voltage, becomes no test nor measure of the motor. The rating then is its intermittent capacity of 50 horse-power at full voltage for a given length of time. A motor properly designed for this load with respect to efficiency will have a low temperature rise in service, so the rating will properly be its intermittent capacity for some length of time as will produce the temperature rise in service, say, 30 minutes.

Draw-bridge Motors

We will now consider a motor for draw or lift bridge work. To lift the bridge requires 50 horse-power at the motor shaft for one minute, the bridge to be lifted every 100 minutes. The time for which power is on is one minute out of each 100, or 1 per cent. of the time. The average power of the motor is ½ horse-power and the average voltage applied 1 per cent. of the normal. Obviously no continuous rating at 5 horse-power (square root of mean square), or average ½ horse-power at 1 per cent. of the normal voltage would serve to test the motor. The proper test will be its intermittent rating of 50 horse-power on full voltage for a short time, say, 15 minutes. Obviously a motor of 50 horse-power continuous capacity is too large; what is needed is a motor with as small a continuous capacity as consistent with efficiency but of 50 horse-power intermittent capacity for 15 minutes.

Summary

In the foregoing I have endeavored to show that the characteristics of the work to be performed determine not only the design of the motor, but the method of its rating.

a. For constant and continuous capacity a motor should have a continuous rating only, with no overload of intermittent capacity.

b. For part continuous and part intermittent work a motor should have a continuous capacity with a certain overload or intermittent capacity.

c. Where variable speed is wanted, the motor should have a series field or a combination of shunt and series excitation.

d. For intermittent work, such as railway motors, the field windings should be series and rated on their intermittent hourly capacity.

e. For crane and hoist motors the series field is required on account of speed characteristics, and the rating should be its intermittent capacity for a short time, say one-half hour.

f. For lift- or draw-bridge motors the series field is required, and the rating should be its intermittent capacity for a still shorter time, say 15 minutes.

PORTABLE VENTILATION SET

By E. F. Dutton.

The portable ventilation set, three views of which are shown on page 150, is designed to meet the requirements of the United States navy for temporary ventilation of compartments which are not supplied by the ship's ventilation system, such as coal bunkers, double bottoms, etc. The set is ordinarily placed in some convenient location near the entrance to the compartment, and the air delivered through a temporary hose or pipe.

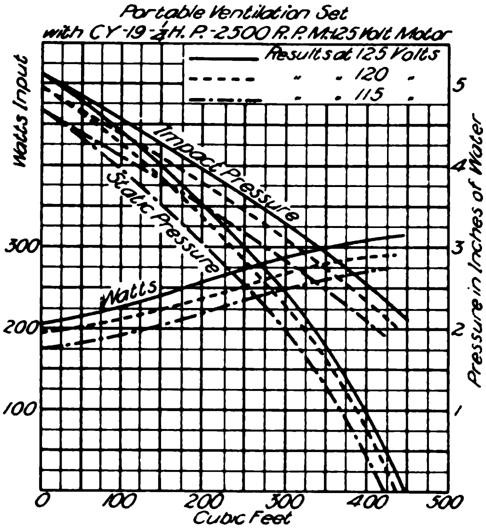


Fig. 1

The outfit consists of a cast shell fan driven by a one-quarter horse-power totally enclosed series motor, having a normal speed of 2500 r.p.m. at 125 volts. The motor may also be wound for 80 or 220 volts.

The navy requirements for this set are 425 cu. ft. of air per minute. The complete action of the fan is shown in Fig. 1, where the impact and static pressures and watts input are indicated for air deliveries obtained with outlets varying from an entirely closed to an unrestricted opening, these curves being taken with the motor running on 115, 120 and 125 volt circuits.

The navy specifications are prepared with a view to obtaining a light and compact set, and in this design particular attention has been given to these requirements, the dimensions and weight being as follows:

Length parallel to shaft, 12½ in.
Height, 16⅜ in.
Width, normal to shaft, with horizontal discharge, 16¼ in.
Outside diameter of outlet, 411.16 in.
Weight, 80 lb.

The general construction is shown in the exploded view of Fig. 2. The fan shell is attached to the magnet frame of the motor, and the complete set is supported upon a malleable iron tripod situated beneath the motor. The bolts for attaching the casing to the magnet frame are spaced 90° apart, allowing the casing to be assembled for horizontal or vertical discharge, as shown on page 150. Handles are provided for convenience in transportation.

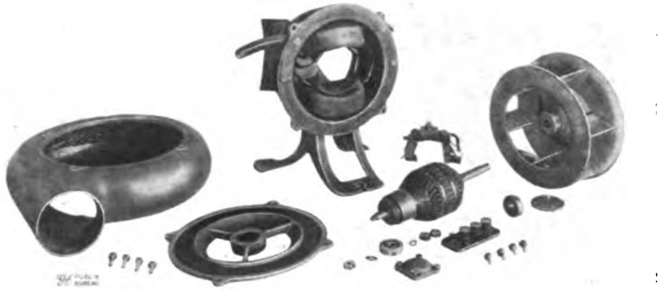


Fig. 2. Exploded View of Portable Ventilation Set

The circular magnet frame is of cast steel, and is provided with a front end shield which has two openings for access to the commutator, these being closed by covers swinging horizontally and held by latches. Suitable protecting binding posts are to be supplied. The armature and fan wheel are carried between two ball bearings, one of which is located in the end shield, and the other at the fan inlet.

The fan casing is of cast iron, with an opening in each side of sufficient diameter to allow the removal of the wheel. The wheel is of sheet steel, the side next the armature being of such a diameter and shape that it acts as a separating plate between the fan and motor.

No starting rheostat is required with this set.

AN INTERESTING APPLICATION OF SINGLE-PHASE MOTORS

The accompanying cut illustrates a very interesting and up-to-date application of a General Electric single-phase motor, in connection with the manufacture of gas stoves.

Some years ago, shortly after the advantages of the application of motors to machine tools had been practically demonstrated, a few progressive establishments initiated the practice, now largely in use, of machining heavy castings *in situ* by bringing the various tools required to perform the successive boring, planing or grinding operations, to the work; and the new method, having been found very economical and capable of eliminating a great deal of delay in shifting heavy masses from machine to machine, with the attendant lining up, has extended widely throughout the whole domain of machine shop practice.

The advantages of moving the electrically-driven machine to the work, rather than the work to the machine, have now become so apparent in the case of machine shop practice, that a general movement along these lines has invaded a great many other classes of manufacturing industry. In the manufacture of stoves, for instance, it is essential to blacken and polish them very carefully before they are shipped from the factories where they are made, both in order to protect the iron from rust, and to give them an attractive appearance to facilitate their sale. In most factories, until recently, it has been necessary to transport the stoves on hand trucks, one or two at a time, from the assembling department to the polishing department, and after the polishing was completed, to remove them by the same method to the store room.

By means of an electrically-operated polishing apparatus, which has been perfected by the Coates Clipper Manufacturing Co. of Worcester, Mass., manufacturers of stoves are now enabled to carry the polishing machine from point to point, and thus avoid a great deal of heavy handling, which is not only expensive, but frequently results in more or less damage to the goods handled. Several manufacturers of gas and coal stoves have adopted these equipments, and find them of the greatest utility.

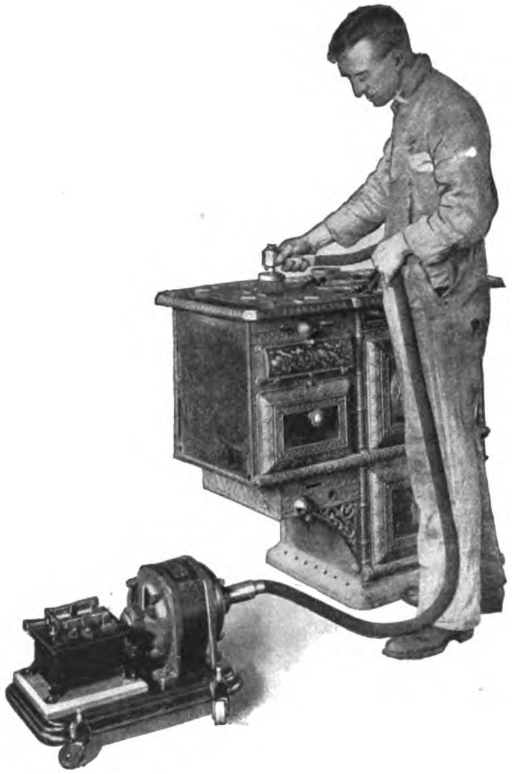


Fig. 1. Stove Polishing Apparatus Driven by 1/2 h.p. Single-Phase General Electric Motor

The illustration shows a ½ h.p. single-phase General Electric motor and starting box, mounted on a special truck provided with swivelling castors. Connected to the motor is a Coates flexible shaft, leather covered, carrying an angle head to which various brushes, suitable to the work in hand, may be immediately attached or removed. The motor is fed from the electric supply through a long heavily insulated flexible cord, adapted to the rough handling incident to its usage in a stove works.

It is quite evident that outfits of this character not only serve a very useful purpose in connection with the manufacture of stoves, but may also be used to great advantage in stove stores for keeping the stock free from dust and dirt, and for renewing the polish of the black portion of the stove, as well as that of the nickel trimmings.

THE LOCKING SOCKET

The necessity for a special socket to protect customers from the petty thief who makes a practice of stealing lamps has led the General Electric Company to design a socket with a locking device.

This socket is intended for use in public buildings and similar places where lamp stealing is often a great nuisance.

The design of this socket is such that in order to insert or remove a lamp from the socket it is necessary to turn a key in the locking device. When the lamp is in position it swivels freely, and cannot be taken out except by locking the socket with the special key, thus clamping the screw shell and preventing it from turning. It may be worthy of mention that this feature is contrary to custom, since it is necessary to unlock the device in order to make it proof against thieves.

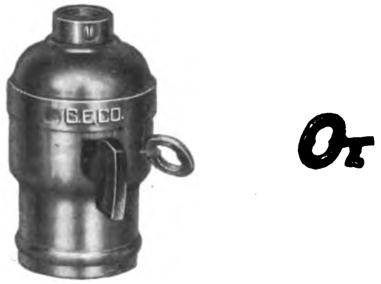


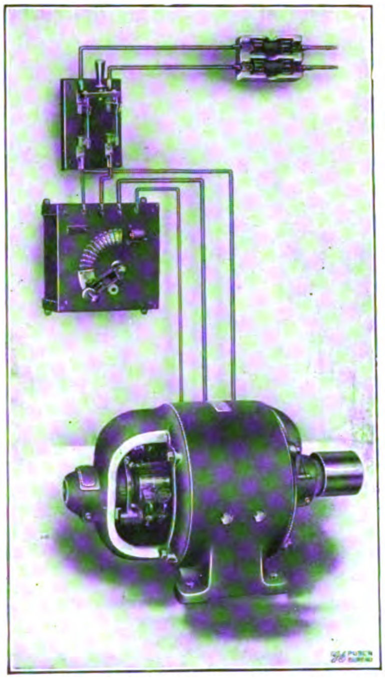
Fig. 1. Locking Lamp Socket and Key

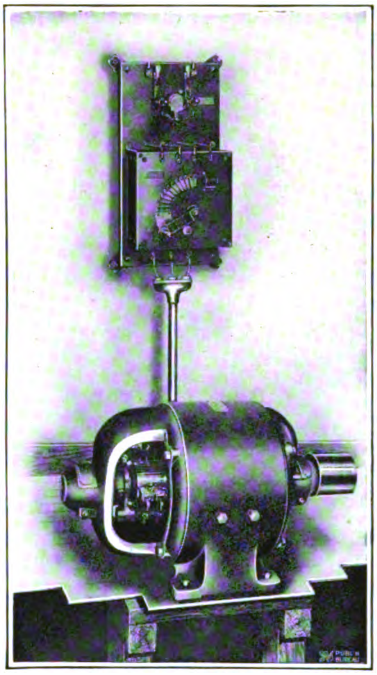
The socket and the locking key are shown in the accompanying cut and it should be noted that the locking feature has been introduced without in any way detracting from the neat appearance of the standard socket.

General Electric Company

Motor Starting Equipments

The Usual Practice *vs.* The Recommended Way


A 15 H.P. MOTOR WITH GENERAL ELECTRIC STANDARD CR 107 RHEOSTAT, SWITCH AND FUSES


A 15 H.P. MOTOR WITH GENERAL ELECTRIC STANDARD CR 135 PANEL

THE USUAL PRACTICE

— scattered parts
— large wall space
— many connections
— chances of error

THE RECOMMENDATION

— a self contained unit
— compact simplicity
— correct connections
— reliable ruggedness

The usual practice *may* continue to satisfy but the recommendation is *sure* to be right, look right, work right and prove an economy

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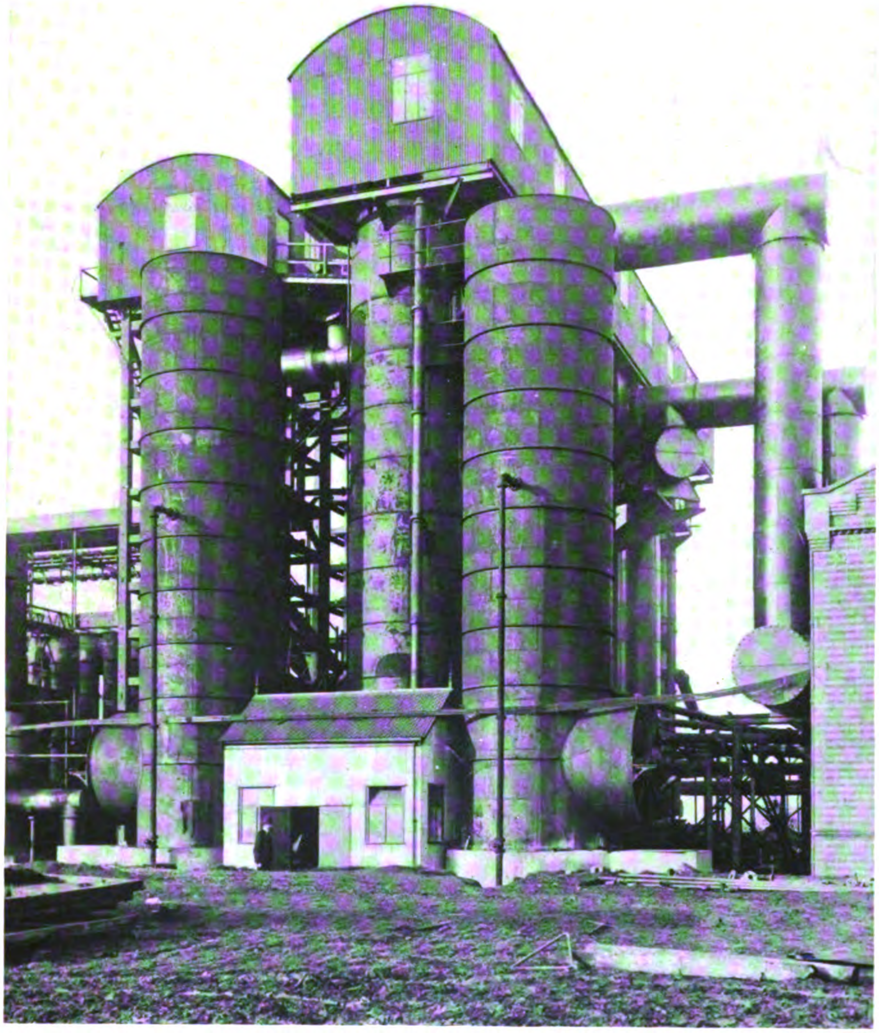
APRIL, 1908

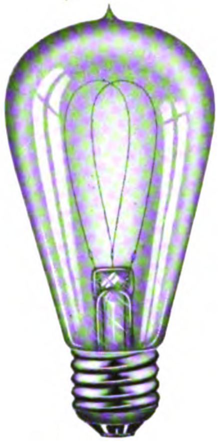


Towers of the South Staffordshire Mond Plant, Power Gas Corporation, Ltd.,
Dealing with Gas for 30,000 H.P.
(See page 199)

General Electric Company

Edison GEM Lamps

50 Watts 20 C.P.



Edison Gem

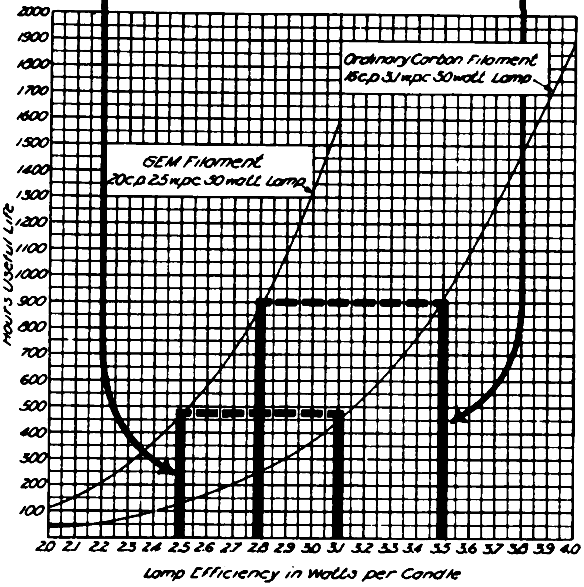
50 Watt Lamp

gives central stations using 3.1 w.p.c. lamps the same output per lamp as at present, thus avoiding the necessity of increasing number of consumers or lamps connected per consumer

The 50 Watt Edison GEM Lamps give 25 per cent. more light

and consume but 2.5 w.p.c. with the same useful life as carbon lamps at an efficiency of 3.1 w.p.c.

Can also be operated at 2.8 w.p.c. to give the same useful life as carbon lamps at 3.5 w.p.c.



Useful life curves of New GEM Filament Lamp and present Carbon Filament Lamp

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1566

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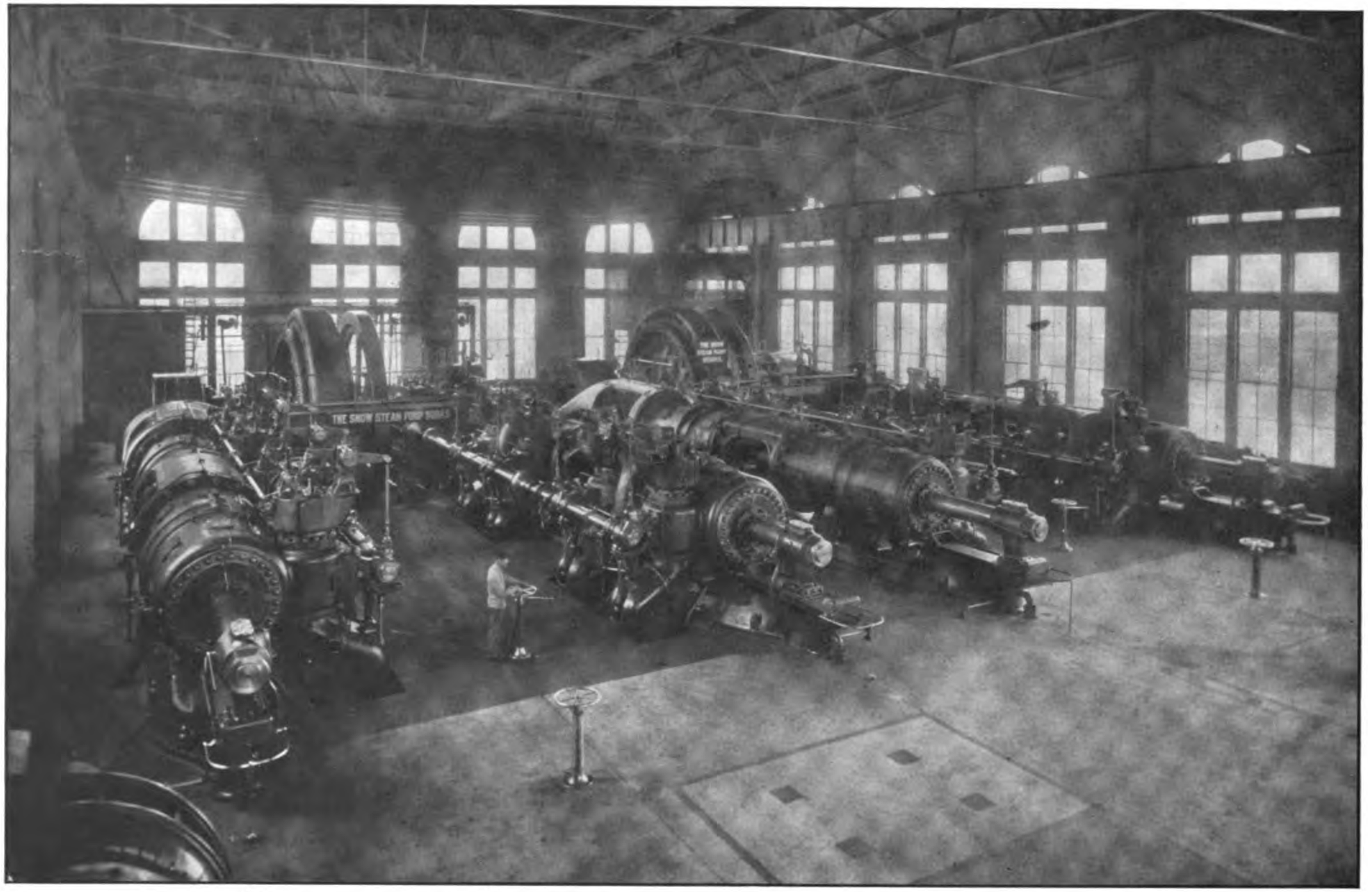


2,500 Kw. Twin Tandem Gas Engines, California Gas & Electric Co., San Francisco, Cal.

Vol. X, No. 5 SCHENECTADY April, 1908

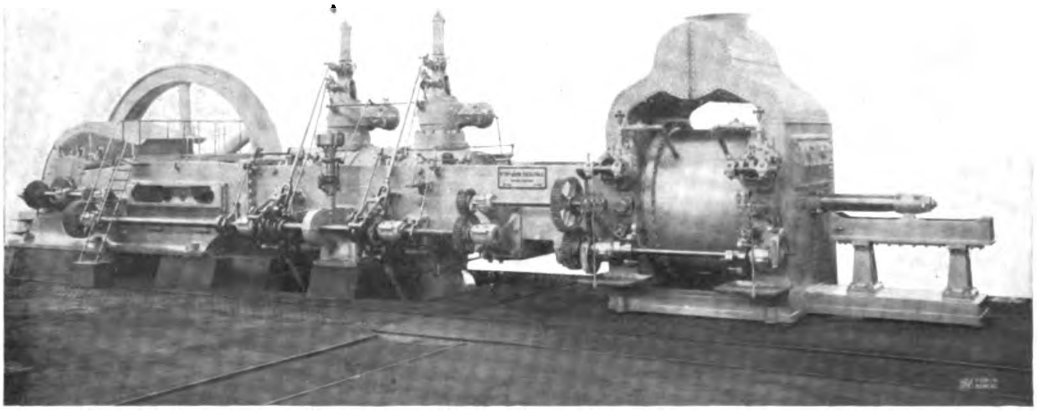
GENERAL ELECTRIC REVIEW

GAS POWER*

By H. H. Suplee

Editor of Cassier's Magazine

It is not my intention to talk about the gas engine from the beginning, or to describe the details of construction, or go into the elementary matters in connection with it. I think most of you are familiar with those points. What I shall try to talk to you about is the important transformation which has been going on during the past ten years in the generation of power by the use of gas engines of large size, in power plants for which the gas engine was formerly considered altogether inadequate.



Later Type of Blowing Gas Engine as Built by The John Cockerill Works, Seraing, Belgium

It was long ago recognized that an air engine, as it was then called, using air or some fixed gas (a gas which does not change its state as steam does, from water to vapor and from vapor back to water again) would be an efficient medium for the conversion of heat into power, and Professor Rankine clearly defined the theoretical possibilities of the air engine many years ago. The practical obstacle to its use lies in the fact that it is very difficult to heat a large body of air from the exterior. It was not until the gas engine became extensively used, burning its fuel in gaseous form within the body of air, that the air engine was shown to be a commercial possibility. The gas engine is really an air engine in which the fuel is burned in the midst of the air instead of being consumed on the outside and heat conducted through the walls of the chamber.

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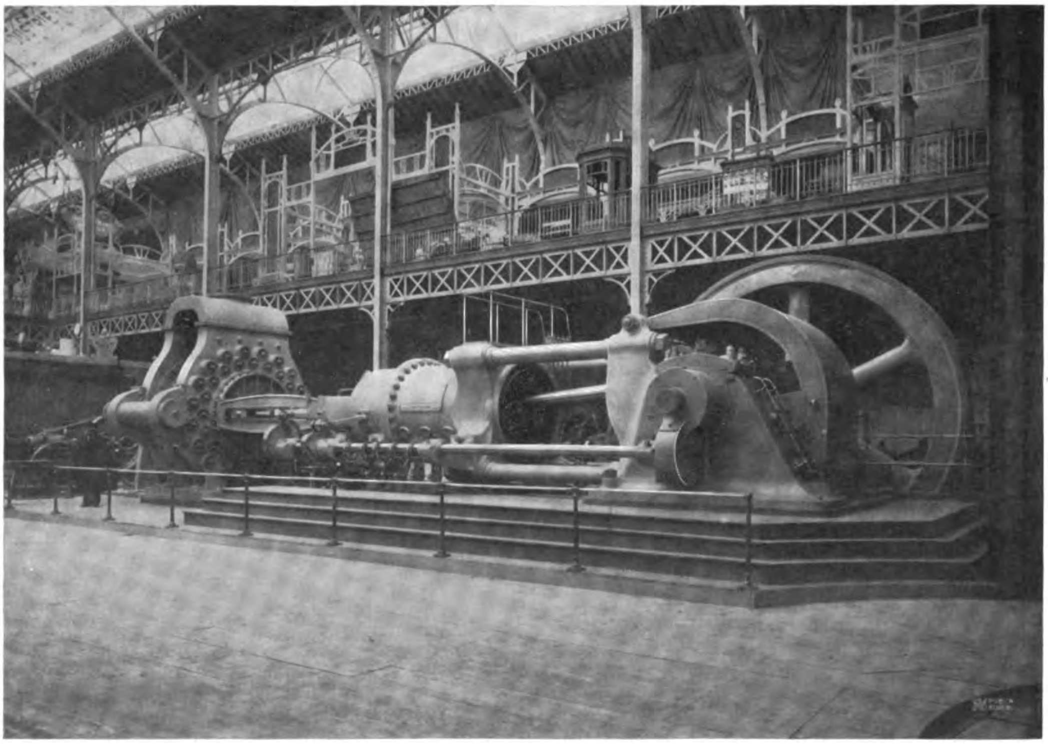
*Lecture before the Schenectady Section, A.I.E.E. February 6, 1908.

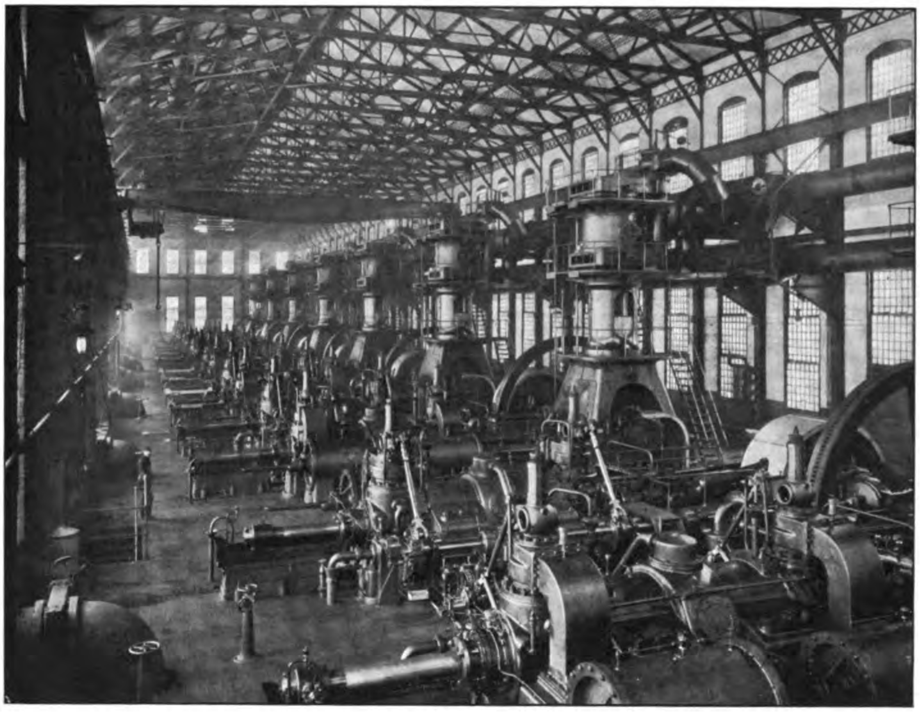
The early gas engines of small size, using city gas and driving printing presses, etc. were used only because they were convenient. The high cost of the fuel made them expensive, but they were convenient because they could be started and stopped instantaneously, and cost money only while running, and thus had certain advantages.

About fifteen years ago a brilliant idea occurred to Mr. B. H. Thwaite, of London. This was, that in the combustion of coke in a blast furnace for the manufacture of pig iron, there are produced large volumes of gas suitable to be used in the cylinder of the gas engine. There is thus here a tremendous amount of cheap fuel all ready for use, and at once engineers began to consider the possibility of using that fuel in the gas engine. A portion of this gas had been burned under the boilers to supply steam for the engines, and some was used in heating the air blast, but a large portion of it was wasted. This discovery proved to be the inducement to build large gas engines. In 1894, Mr. Thwaite published a short statement calling attention to this fact, and soon after he made some experiments in Scotland with a small gas engine fed by blast furnace gas, and found that it worked very well. Almost at once builders of heavy machinery, particularly those interested in iron works and iron manufacture, began to consider the possibility of use of gas engines, at first for blowing the blast to the furnaces and then for the generation of power to drive the machinery. About the time that this was being considered, the Paris international exposition of 1900 was held, and among the mechanical exhibits there shown was one attracting the attention of everyone interested in mechanical matters. Up to that time the largest gas engine in service was about 250 h.p., and this was considered a very large one.

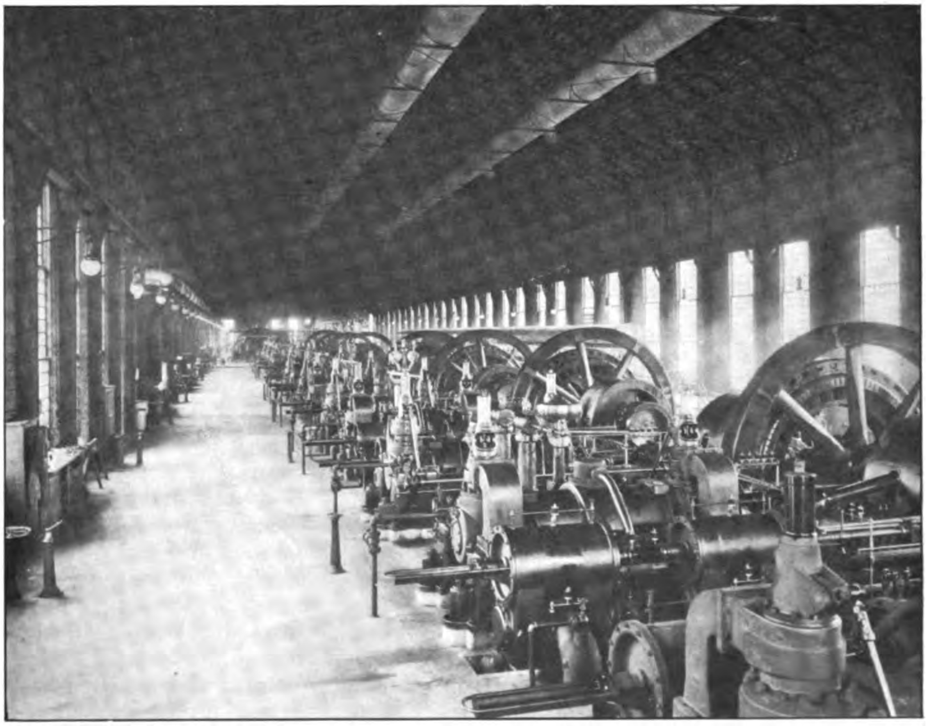


1,000 Kw. Cockerill Blowing Engine. Exhibited at the Paris Exposition in 1900

In 1898, Mr. Dugald Clerk, one of the leading experts in gas engine design, and the inventor of an important type of gas engine, made a prediction. He said "There is little doubt that in ten years gas engines of 1000 h.p. will be as common as engines of 100 h.p. are now." Mr. Clerk's ten years have ex-



16-2000 Kw. Gas Engines in the Power Plant of the Lackawanna Steel Co.
Built by the De La Vergne Machine Co., New York

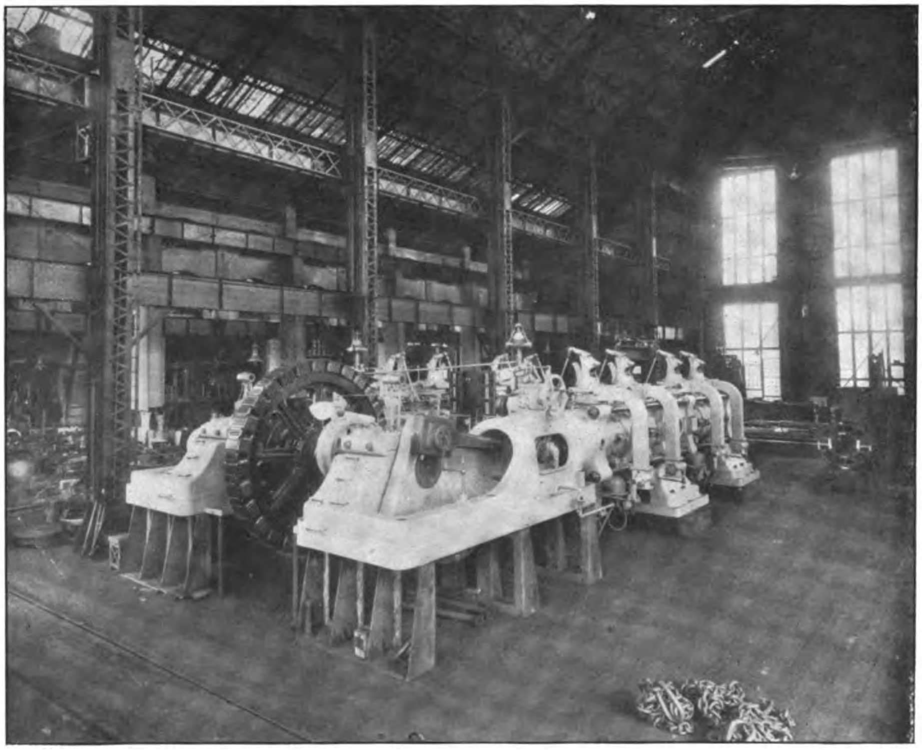


8-1000 Kw. Gas Engines in the Power Plant of the Lackawanna Steel Co.
Built by the De La Vergne Machine Co., New York

pired and gas engines up to 4000 h.p. are in use, and his prediction has been abundantly fulfilled.

At Paris in 1900 there was one gas engine of 1000 h.p. exhibited by the John Cockerill Works of Liège, in Belgium. This was built for a blast furnace blowing engine. I happened to be in Paris in the spring of that year, and went to the exposition, and saw this engine and admired it exceedingly. I was called away from Paris, and two months later went back. There was a large sign hung over this engine stating that this machine had been sold 95 times. They had taken orders for 95 of these machines by showing one. Some time afterward I saw the mate to it driving a blowing engine at the Cockerill Works. It was running beautifully and giving excellent service. In another room was a 200 h.p. gas engine belted to a dynamo, and furnishing power for service in the works. That was in 1900, and at that time all the rest of the power was furnished by steam engines. Each year since then they have been installing gas engines more and dropping off more steam engines. To-day the estimated power output in that works is twenty-four million kw. hours, all produced by gas-power from gas taken directly from tops of their blast furnaces. That gives you an idea of the advance that has been made.

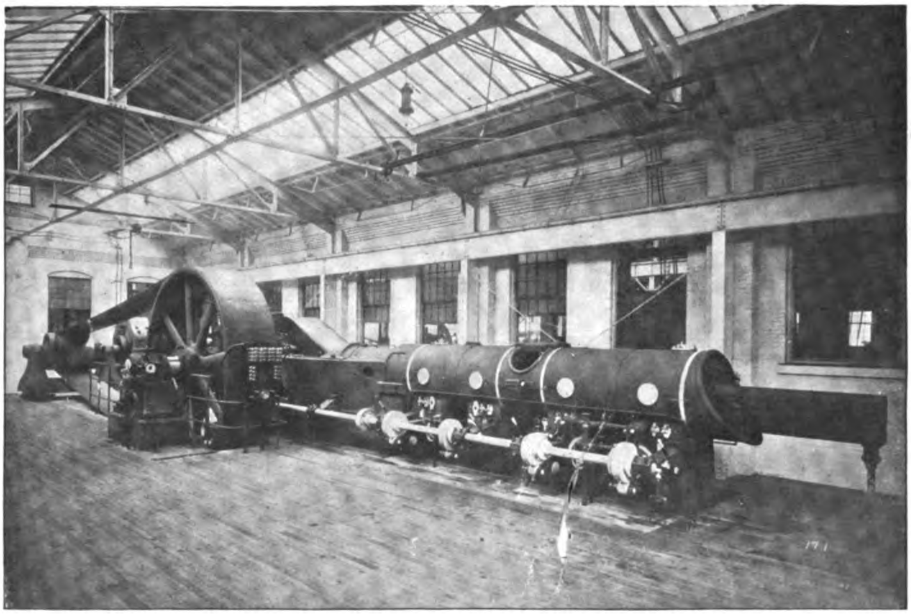
In this country the first attempt was made by the Lackawanna Works when they moved from Scranton to Buffalo, and they naturally had some difficulties to face. They are running to-day a plant consisting of 16 blowing engines of 2000 h.p. each, and one of 8 electric units of 1000 h.p. each of General Electric make.



1700 H.P. Gas Engine for Driving Electric Generator. Built by the William Tod Co., Youngstown, Ohio, for the Carnegie Steel Co.

The U. S. Steel Corporation is now having a large number of gas engines built for use in its plants and at its new Gary plant. The Westinghouse Machine Co. has built two 3000 h.p. blowing engines for the Edgar Thomson Works.

Coal is a natural source of energy, but our supply of it is limited and we have been using it at a wasteful rate. Broadly speaking, a gas engine will produce a horse-power with about one-half the amount of coal required for the steam engine; that is, the coal supply of the world, if used in the generation of power, would either produce twice as much or last twice as long if used with the gas engine rather than the steam engine. Coal can be burned in the gas producer and the gas used in the gas engine with twice the efficiency obtained in burning it under a boiler. Furthermore, an advantage of gas power lies in the possibility of the utilization of the fuels of low grade which cannot be used so successfully under the steam boiler.

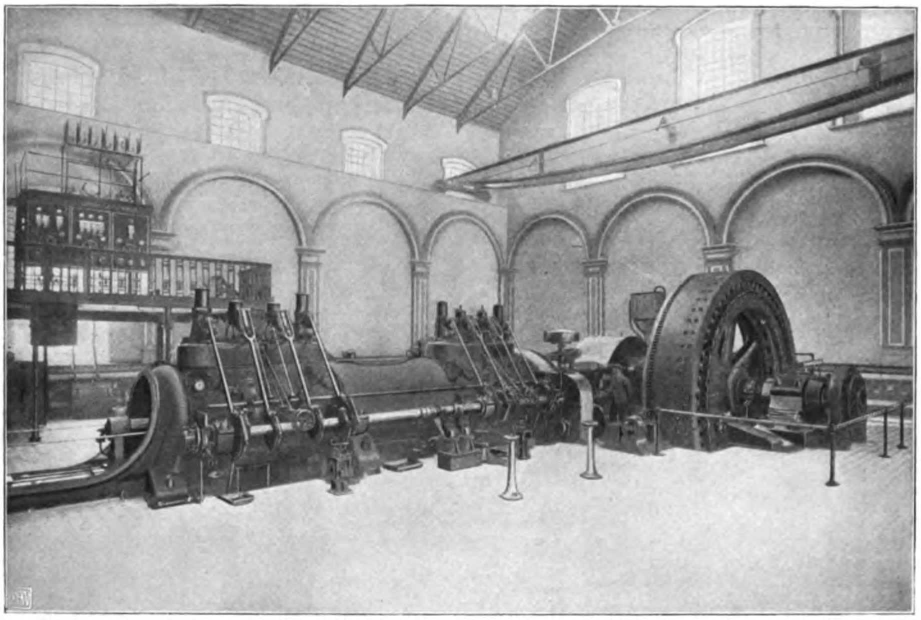


500 H. P. Gas Engine Built by the Sargent Engine Co., Driving 300 Kw. Direct Current Generator

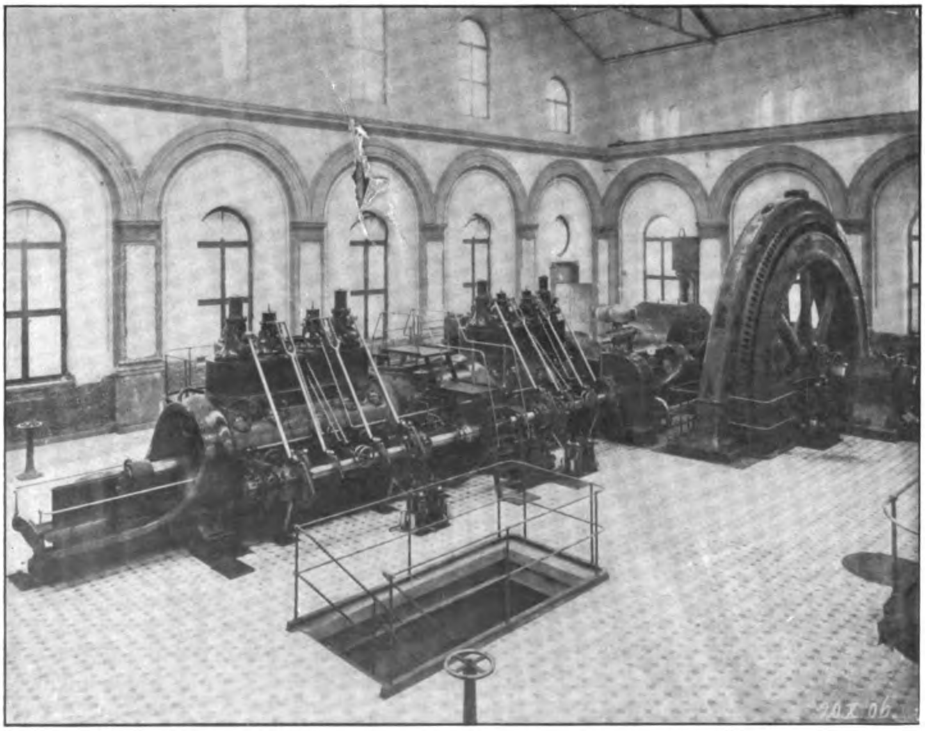
Lignites, peats, bone coal, soft coal, coals having a large proportion of impurities, such as sulphur and ash, all these are capable of being used to good advantage in the gas producer; so that in the efforts for the conservation of our supply of natural energy, the gas engine is going to be an important element. The importance of this will be realized when it is understood that the national government has taken up the matter of preserving our natural resources, endeavoring to check the enormous waste of our natural sources of wealth, including the question of the waste of fuel.

Although the gas engine is still in its infancy, the heat efficiency is practically double that of the steam engine. The vertical type of machine works well with city gas, and in places where natural gas is available. The gas is clean, and this type works well; but there is a certain amount of dirt and dust in blast furnace gas, and this sometimes gets into the machine and causes trouble. The blast furnaces in Belgium, where the first engines were built, produced a fairly clean gas and there was little trouble experienced. When similar engines went to different parts of Europe, and were installed in works producing dirty gas, the dust and dirt soon gave trouble. Then it began to be realized that something more must be done, and a good deal of the seven years' experience has been devoted to the cleaning of gas. To-day, however, there are a number of devices by which the gas may be satisfactorily cleaned; but no matter how well the gas is cleaned the dust will accumulate upon the top of the piston in a vertical engine. With the horizontal type it will generally blow out without doing serious harm.

In the gas turbine the turbine part is practically the same as the steam turbine. The gas has to be produced continuously and delivered against the buckets or blades of the wheel in the same manner as steam in the



1200 H. P. Nürnberg Double-Acting Single Tandem Gas Engine Driving 825 Kw. Three Phase Alternator at Powell Duffryn Coal Co.



Blast Furnace Gas Engine Built by the Gas Motoren Fabrik, Nürnberg steam turbine. That means ordinarily that the fuel has to be burned in a closed chamber under pressure continuously, maintaining combustion at constant pressure. Air has to be blown through a nozzle and mingled with the gas under pressure, and the gases produced by the combustion discharged upon the blades of the wheel. This means the accomplishment of two very difficult things. In the first place, air must be supplied under pressure continuously and efficiently; and secondly, very high temperatures have to be dealt with. Some good experimental work has been done and more will follow, and I should not be surprised if the gas turbine should ultimately become an important prime mover as well as the reciprocating engine, each in its place. There is room for each, but in many cases the advantages of continuous rotary motion will outweigh any deficiency in economy, and it is possible that we may improve the gas turbine and get a higher power for weight and volume than with the reciprocating engine.

The illustrations cover only a portion of the work which has been done in late years, but they will serve to show the extent to which the large gas engine has been developed during the past seven or eight years.

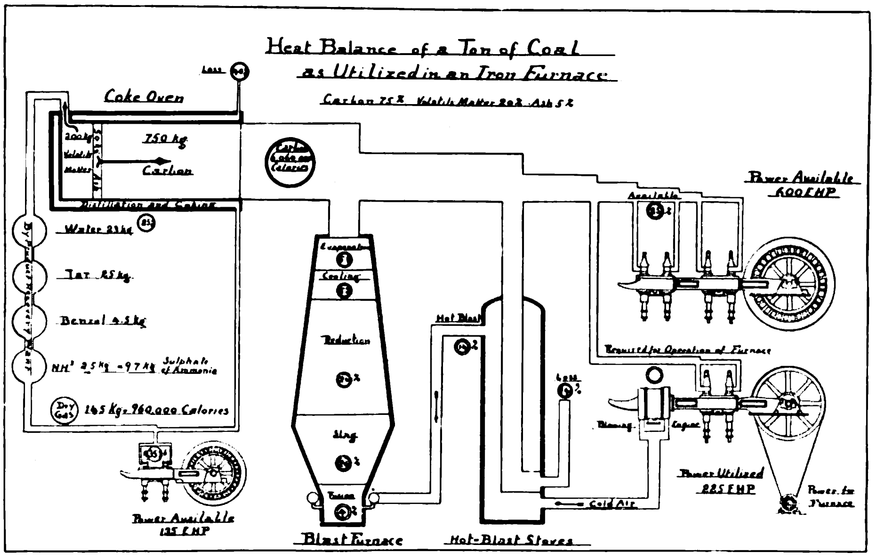
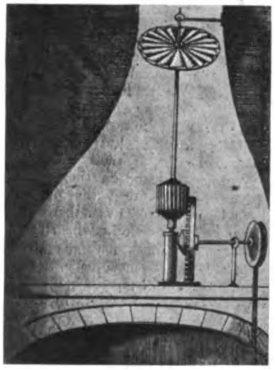


Diagram Showing the Possible Utilization of a Ton of Coal in the Coke Oven, Blast Furnace and Gas Engine

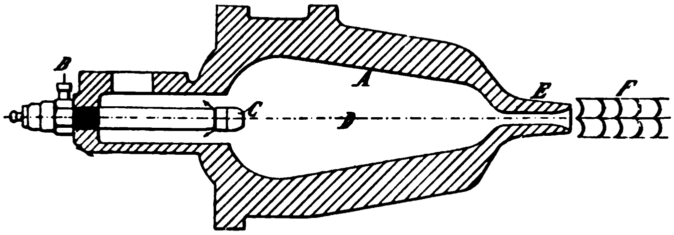
Among them will be seen the large gas engine built by the John Cockerill Works at Seraing, near Liège, in Belgium. This is the engine which was shown at the Paris Exhibition of 1900 and to which I have already referred. It was designed for operation with blast-furnace gas, but at the Exposition it was run for a short time each day with city gas. It is shown directly connected to the blowing cylinder for supplying air to the blast furnace and it developed 600 h.p. with furnace gas, or about 1000 h.p. with city gas. Shortly after the Paris Exposition I visited Liège and saw a similar engine to this in continuous operation supplying blast for the furnaces there. This is the first gas engine, to my knowledge, which attained 1000 h.p., and I believe the companion engine is still in operation at the Cockerill Works.

A later design of blowing engine of the same company is also shown, the principal modification in these engines having been in mechanical details, such as provision for more effective cooling by water circulation, and by the introduction of arrangements to provide for the expansion and contraction strains.

In engines of this sort the power varies according to the richness of the gas but not to such an extent as might be imagined since it is the heating value of the *mixture* of air and gas which is put into the cylinder which determines the power and not the calorific value of the gas itself. With a rich gas a greater proportion of air is used, while with a lean gas a greater quantity of gas in proportion to air is put into the mixture. As a matter of fact, the heating value of illuminating gas or natural gas is six or seven times that of blast furnace gas, while the difference in power in the engine, using the different gases will vary only about 40 to 50 per cent.



The "Smoke Jack"
The First Gas Turbine



Combustion Gas Turbine
A.—Combustion Chamber. B.—Fuel Inlet. C.—Fuel Sprayer.
E.—Expansion Nozzle. F.—Turbine.

Among the illustrations also will be seen the views of the plant of the Lackawanna Steel Company, near Buffalo, these being Koerting engines of the two-cycle, horizontal type. In one room there are sixteen engines of 2000 h.p. each, driving blowing cylinders, and in the other there are eight engines of 1000 h.p. each, direct connected to electric generators. These engines are provided with separate pumps for the air and the gas and thus are enabled to make one power stroke every revolution.

Among the other American gas engines of large size illustrated will be seen a set of 1700 h.p. engines of the four-cylinder, double-acting type, in course of erection in the shops of the William Tod Company of Youngstown, Ohio, built for the United States Steel Corporation and also a 500 h.p. Sargent gas engine, belted to a 300 kilowatt, direct current generator in the Works of the Wellman-Seaver-Morgan Company, at Cleveland, Ohio.

There is also shown a view of the large plant of the California Gas and Electric Power Company at San Francisco containing four sets of twin tandem gas engines, each pair developing 2500 kilowatts. These engines were built by the Snow Steam Pump Company of Buffalo.

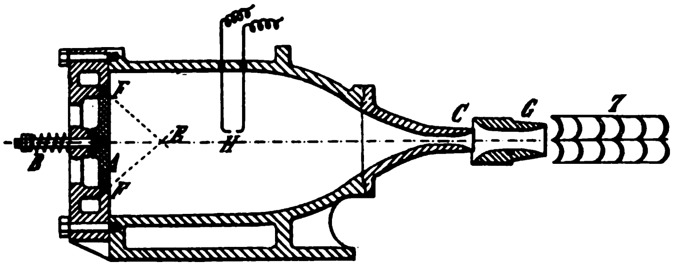
Other views show German engines built by the Nürnberg Works, the details being given under the illustrations.

A special form of German engine illustrated is that of the Oechelhauser type, this being especially designed for blast furnace gas. In these engines the cylinder is open at both ends and contains a pair of pistons, the gas being run between them and forcing them apart at each stroke. This involves a double set of cranks, but it simplifies the valve construction, and this design has been extensively used in Germany in connection with the development of power from furnace gas.

An interesting diagram is that prepared by M. Leon Greiner, of the Cockerill Works for illustrating the power to be obtained from a ton of coal. The coal is first delivered to the coke oven, from which, in addition to the coke and the chemical by-products, a surplus of valuable power gas is obtained, capable of producing 135 h.p. for every ton of coal coked.

The gases discharged from the blast furnace are used, a portion for heating the blast, and a portion for driving the blowing engines and machinery of the furnace, this requiring gas equivalent to 225 h.p. for each ton of coal burned. The balance of the gas from the blast furnace is capable of producing 600 h.p. available for sale, so that by taking advantage of all the possible opportunities for the saving of fuel, there is developed 735 h.p., over and above what is needed for the operation of the furnace.

Probably the oldest form of gas turbine is the old-fashioned "smoke jack," of which an illustration is shown, taken from Bishop Wilkin's "Mathematical Magic" dated 1680, although such a machine was described by Cardan as long ago as 1550. The propeller wheel in the chimney was caused to revolve by the ascending current of hot gases from the fire, and the motion was transmitted by gearing and belting to the spit on which the joint of meat was carried before the fire. The amount of power developed by such a machine was not great, but since it replaced the labors of the turnspit dog formerly employed, we must admit that it was at least one "dog-power."



General Arrangement of Explosion Gas Turbine

An early form of gas or hot-air turbine is that of Stolze, this consisting of two turbines on one shaft, one acting as an air compressor, and the other as a power turbine, that air being forced through a heating chamber between the two wheels, but this machine, although operative, has not been commercially developed. Other designs for gas turbines are shown in the diagrams, one interesting form being the explosion turbine.

This consists of a combustion chamber, one end of which is closed by a large valve opening inward, this valve having the small openings for the gas in the face of the valve-seat. It is a well-known fact that when a mixture of gas and air is exploded there is first a sudden expansion, followed by the formation of a partial vacuum, due to the combination of the hydrogen and oxygen to form water. This fact was utilized in the

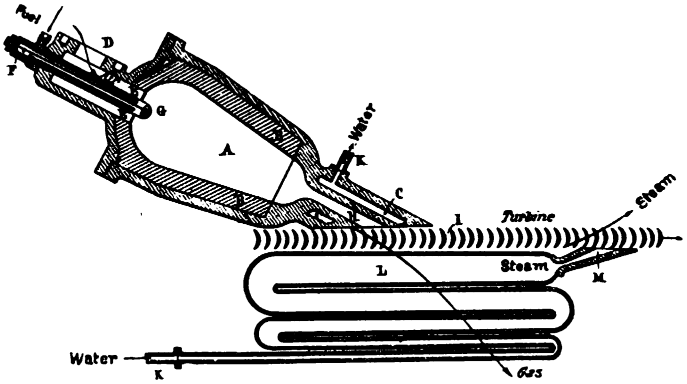
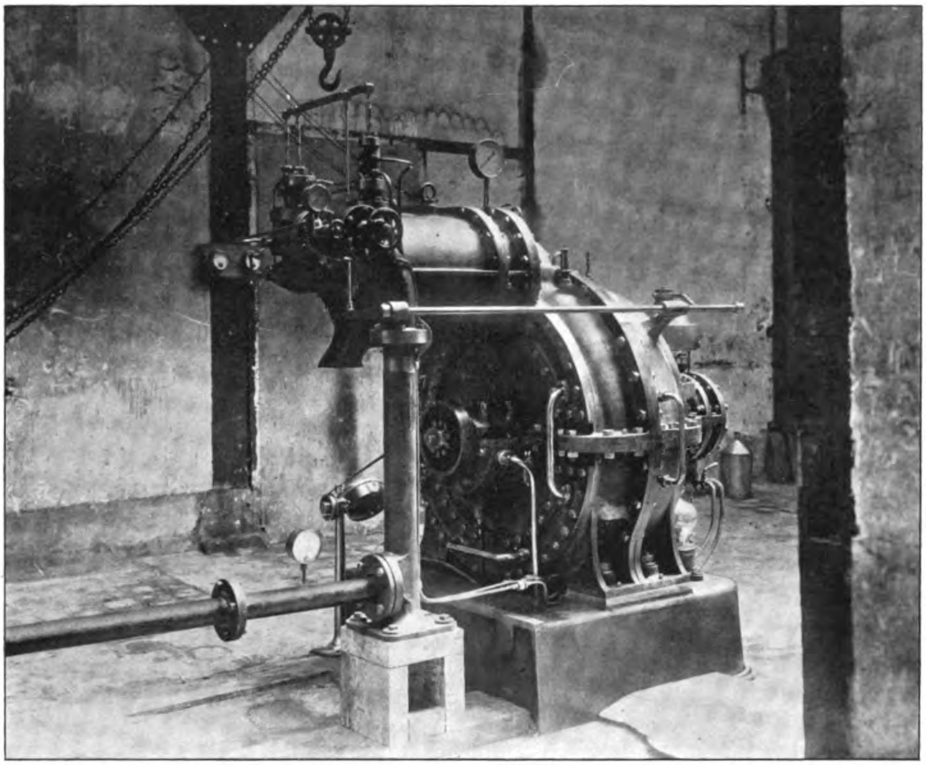


Fig. 6. Mixed Gas and Steam Turbine

Air enters at D, fuel at F, the ignition is made at G. The combustion chamber A is lined with carborundum. The nozzle H is water-jacketed, and the hot water passes to the steam generator L, which is heated by the exhaust gases from the turbine. The steam acts to propel and cool the wheel by the nozzle M old Otto & Langen gas engine under a piston, and is here applied in a combustion chamber. The mixture is ignited by the electric spark, and the explosion discharged against the blades of the turbine wheel. The formation of the vacuum draws in another charge which is ignited and the operation is repeated. Such an apparatus has made 60 to 80 explosions per second, and gives practically a continuous discharge upon the wheel. So far this apparatus has not been developed, and its efficiency is very low, but it has possibilities.

In the case of the pressure gas-turbine the air and gas are delivered under pressure to a combustion chamber, where a continuous combustion is maintained, the products being discharged upon the buckets of a turbine wheel. In practice such a chamber is lined with carborundum, backed with an elastic filling of asbestos, the nozzle being made of carborundum also. The chamber is water-jacketed, and the water discharged into the nozzle as steam to cool the gases. The exhaust gases are also delivered over the pipes of a coil boiler and the steam thus produced delivered upon the same wheel. These principles are used in the gas turbine of Armengaud and Lemale, and an illustration of such a machine of 300 h.p. is shown as erected in the experimental shops of the Société des Turbomoteurs at Paris. M. Rateau, the well-known designer of the steam turbine which bears his name, has designed a rotary turbine compressor for use with this machine, which gives an efficiency of 65 per cent., and tests and studies of this machine are now under progress in France.

Thus we see what has been accomplished in the generation of power from gas since Mr. Clerk made his prophecy in 1898. The power of blast-furnace gases is being utilized, the gas turbine is well on its way, and the fuel cost of the steam engine has been cut in two.



The Armengaud and Lemale Gas Turbine, Showing Combustion Chamber, With Air and Fuel Connections

I do not wish to encourage invidious comparisions between the cost of power from steam engines and gas engines. Both motors have their place, and gas power is not going to drive out steam any more than electric lighting drove out gas lighting. More important than mechanical details in the development of gas power is the development of the commercial side of the industry. Selling power is a very different business from the selling of pig iron, and iron manufacturers may find all the value of the power produced from their waste furnace gases consumed in marketing it. Probably the solution of this portion of the problem will be found in the development of selling companies, taking the power from the iron works in quantity, and attending to the distribution and general details of the business independently. It is often said that it costs as much to market a product as to make it, and probably gas power is no exception to this rule.

The gas engine has passed the stage when it was considered as a small affair for the operation of printing presses, laundry machinery and the like, and it has become an important type of prime mover for many purposes. The power house engineer will find it of continually increasing importance in many departments of his work, and even for the driving of electric machinery, such as alternators in parallel, and similar exacting work, it will be found capable of holding its own with the best modern forms of steam engine. Its progress during the next ten years cannot be predicted, but a motor which now drives practically all our automobiles, which is making the aeroplane a possibility, and yet which has risen in capacity from 250 to 4000 h.p. within ten years past cannot fail to have future possibilities worthy of consideration.

CURRENCY AND FINANCE

PART II

BY HENRY W. DARLING

TREASURER OF THE GENERAL ELECTRIC COMPANY

Reserves

Let me now touch upon the subject of reserves. Those responsible for the National bank system evidently thought, that in authorizing the establishment of small banks in country districts, the management would probably devolve upon men untrained and inexperienced in the science of banking; and as some sort of safeguard, they provided in advance for the maintenance of a certain fixed percentage of reserve, in lawful money of their total deposits.

Certain cities, usually one in each state, were appointed as "central reserve cities," and all National banks in these cities are required to hold in lawful money twenty-five per cent. of their total deposits. Other cities were called simply "reserve cities," and the banks therein must also maintain a reserve of twenty-five per cent., but of this one-half may be on deposit in a bank in a central reserve city. Banks in smaller places are required to maintain a reserve of fifteen per cent., of which three-fifths, or nine per cent. may be on deposit in a bank in a reserve city or in a central reserve city.

There is a weakness here which should be pointed out, and which has been the subject of comment: Under this reserve system, deposits of $10,000,000 in non-reserve city banks would call for a reserve in lawful money in their vaults of six per cent., or $600,000. They could carry and count as reserve $900,000 on deposit with reserve city banks, which would make up the fifteen per cent.

These reserve city banks would be required to have only $112,500 cash, and might deposit an equal amount of $112,500 in central reserve cities, who in turn would hold twenty-five per cent. of this on hand, or $28,125 in cash. Thus, the country bank keeps but six per cent. in cash, and of the reserve deposits of the country banks the city bank keeps but 1.4 per cent. in cash. There is therefore but 7.4 per cent. cash, or $740,625 unloaned anywhere against this deposit of $10,000,000 in country banks. If for any reason there should be a drain, or a reduction of $150,000 in the deposits of the country banks out of $10,000-

000,—*i. e.*, only 1½ per cent.—it would call for more cash or reserve money than is kept on hand for the whole $10,000,000 in reserve banks.

Under such a condition of affairs it is easy to understand how a crisis can assume the phase of a bank panic.

The system of a bond secured circulation offers no help in any sudden call for deposits. The bills cannot be got quickly, and the purchase of bonds for their security requires as much money as they furnish. The principle of adequate reserves in banking is fundamental, but wholly unscientific when a rigid regulation by law is attempted, and the various amendments to the law which have been suggested are unlikely to improve matters.

It must be manifest that different classes of deposits require larger or smaller proportions of reserves. Moreover, the character of the loans in which the bulk of the deposits is invested, their maturities, and the security upon which they are based, have a most important bearing upon the subject. Of what avail is an extra 5 or 6 per cent. of reserve if the bulk of the deposits are invested in a fixed or semi-fixed form and not readily available? Banking is just as much a science as navigation or surgery, and the man who will excel in either must undergo the necessary training and study and have wide experience. Caution and vigilance, foresight, and the most thoughtful study of conditions, together with an intimate knowledge of the circumstances of depositors and borrowers, will alone keep the bank safe. It is in times of stress and panic that these matters are severely tested. The prudent banker must always be prepared for the unreasoning demand of an alarmed and panic-stricken community.

The questions of reserves and circulation are closely allied, and are now the subject of keen discussion by legislators, bankers and business men. The resort to an emergency currency to be issued by the secretary of the treasury is more likely to increase than to allay the want of confidence.

This proposed emergency currency based on municipal and approved railroad bonds, is to be heavily taxed to insure its speedy retirement when the exigency has passed; but how can the issuing bank which has to pay the tax control its disposition or compel its return? It is in the hands of the public, which has no interest in it or in the bank of issue, and is entirely indifferent as to what bills it uses or hoards, and all the issuing bank can do is to wait for the return of this currency and refuse to reissue it.

It is a question whether the attempt to fix a proper proportion of reserves to be maintained by law, irrespective of the character of the deposits and of the loans of the bank, does more harm than good. It may have served a useful purpose in years that are past, but in the older states and in the large cities, we have a body of trained and experienced bankers, many of great eminence, to whom such legislative enactments are neither useful nor restrictive. They must be disregarded in times of stress, because that is precisely what reserves are for, and when business is dull and money is a drug, the law is of no account.

Returning for a moment to the question of a bond secured circulation, it is not difficult to predict that before many years it will be entirely abolished, displaced by a system more scientific and perfectly safe.

The National banks have now been in existence for a long enough time, and have come through such periods of prosperity and panic that something very positive can be affirmed as to their stability as a whole.

I do not see any good reason why they should not be organized into State associations, and mutually guarantee the circulation of each and every National bank in the state, by depositing with the treasurer of the United States a percentage, say five, or six, or seven per cent. of the average monthly circulation of each bank, based upon the previous six months; and let this fund, still remaining the individual property of the contributing bank, be available to make up any loss sustained by the insufficiency of assets of a failed bank to provide for its circulation.

The state association would establish a redemption city in every state in the union—preferably another national bank—where the bills issued by the banks in the State of New York, for example, would be daily redeemed in legal tender and swiftly returned for redemption to the issuing bank. By this daily system of redemption it would be impossible to keep afloat more money than is actually required for the wants of commerce, and therefore it would be perfectly safe to allow each National bank to issue its own bills up to the full amount of its paid up and unimpaired capital. The percentage of the guarantee fund would necessarily vary in the different states. It could be made even larger than seven per cent. at the outset, until experience had established a safe minimum rate.

One of the advantages of this mutual guarantee would be the interest taken in one another by all the banks in each state. No bank should be allowed to do business with a smaller capital paid up than $200,000 or $300,000; and in place of small struggling banks, in sparsely settled communities, with too limited business to enable them to pay adequate compensation to trained managers, we would expect to see branches of the banks with large capital and resources, the operations of which would be directed from their headquarters. This was originally the Scotch system, and is now the British system and in successful operation in England, India, Canada, Australia and in all the British Colonies.

It has many advantages, not the least of which is the school that is thus established by each large bank for the training of officers, by transferring them from branch to branch in various capacities. In this way they become heir to the accumulated traditions which are the result of generations of experience.

The theory that deposits gathered up in one locality must necessarily be loaned in that community, irrespective of the character of the business done therein, has long been exploded, and yet it was seriously repeated, and branch banking damned with faint praise, in the report of the commission on banks recently appointed.

The Importation of Gold

> "France once accommodated America with gold at a time when the exchange relations between the two countries did not justify a movement of the metal to this side. When the exchange relations between the two countries do not justify a movement of metal, how does one country accommodate another?"
>
> "But after all is said, the probability is that America will have to worry along without getting sixty million dollars from Paris, and there is the even less consoling reflection that the nominal engagements, made everywhere since the present import movement began a month ago, must be scaled down very materially, if one is to avoid having an altogether exaggerated idea of the amount of the metal that is now headed towards this country. Nominally the announced engagements have reached a total of about $98,000,000; actually they are probably a little more than $75,000,000."

Regarding the above paragraphs, clipped from a newspaper, should America obtain a large sum of money from Paris, upon what securities would the money be transferred to America? Would the actual bullion be transferred, and if so, upon what security?

As a matter of fact, the exports of the country were enormous this fall. In the ordinary course of affairs we would have adjusted the balance between imports and exports by what we call bills of exchange.

These bills are dealt in by bankers and brokers just like any other commodity, and the rate fluctuates according as the balance is in favor of this continent or the other. This is not invariably the case, as the market is sometimes influenced by other considerations.

There is no truth in the statement that the gold recently imported was borrowed. The trade conditions gave the tendency to an inflow of gold to America, and the premium on our currency made it possible and profitable. Taking November and December together, the exports amounted to the enormous aggregate of $411,653,000, and the net export balance reached $208,821,966. France accommodated America by making a price upon her surplus stock of gold that attracted the buyers. Had France felt too poor to spare it she would have put up the price. The Bank of France would have entered the market and paid a price high enough to keep the gold in the country. The actual bullion was bought and paid for. It might have been in bars or in coin. In all probability it was both. Gold is bought and sold like any other commodity.

How is gold transferred into currency?

Gold is the best currency. If a bank can get gold it needs nothing more. It was found more convenient during the panic to import gold than to purchase Government bonds as a basis for obtaining national bank currency.

Clearing Houses

What is the practical operation of the National Bank Clearing House?

The Clearing House is simply a voluntary association of the banks of a city, established for the promotion of their interests, and for mutual protection. They adopt certain rules or by-laws for the conduct of their business and agree with one another, under penalties for violation, to abide by them. One important function that the Clearing House facilitates is the adjustment of balances between its various members. Each day each bank presents the cheques received the previous day against its fellow members, and in turn it is presented with the cheques drawn against it, negotiated by all the others, and the balance is adjusted in favor of or against each bank in legal tender. At the close of the transactions for the day the total debits and credits will just offset one another, the Clearing House being merely the medium of settlement. The total volume of business as tabulated from day to day forms a useful barometer as to the relative activity of financial transactions. During a panic or monetary crisis the Clearing House banks stand by one another on the theory that a failure must affect them all more or less. As in the so-called "Morse-Thomas" chain of banks, a demand upon the part of the Clearing House committee of management for a member bank to purge itself of a dangerous element in its directorate or officials, must have instant attention, or its death knell will have rung. Disregard of proper safeguards or practices, which is contrary to the principles of sound banking, when brought to the notice of the governing board, results in the immediate disciplining of the offending member, and the proper remedy must be applied, or the bank's existence will be imperiled.

On the other hand, a member bank which is unable, through stress of circumstances, to settle the balance against it in legal tender, may deposit satisfactory securities from its treasury assets with the appropriate committee and obtain from this committee a certificate which is received as the equivalent of the legal tender. This certificate is in turn received by some other bank to whom legal tender for the balance due it is not essential. Thus the strong help the weak, and in the presence of a common danger they stand together. In some cities these Clearing House certificates were issued in small denominations, and were used as, and served all the purposes of ordinary bank notes, thus performing the functions of "emergency currency." The necessity for their use having now passed, they have been almost wholly retired, and so far neither loss nor trouble therefrom has been reported..

What is the process from special government action to relieve stringency to the point of actual currency relief?

The Treasurer of the United States is a self-contained banker. His receipts from customs, duties, etc., which as before remarked, are payable in a special form of currency, are withdrawn from circulation and hoarded in the treasury. These payments are usually heaviest when there are the largest demands for currency for other purposes; and this results in stringency and an increase in rates of interest to borrowers, because of the lack of elasticity in the system. The banks have always complained of this withdrawal of currency just when it is most needed, as an unwarranted interference with the ordinary business of the country, causing inconvenience by the fluctuations in the value of money. The secretary of the treasury is not bound to make a deposit of any of this money in the National Banks although he may do so at his discretion. During the recent panic he used this privilege liberally, and even stretched his authority by issuing treasury notes and Panama bonds as a basis for bank circulation in the hope that public alarm might be allayed, and that a normal condition of financial affairs might be restored. For this action he is now being severely criticized.

Money and Rates of Interest Thereon

> "Yesterday renewals were made at 7%, against a rate of 9% charged on Monday, and in the afternoon a supply of funds was offered at 3%, even this low rate failing for a time to attract borrowers."

When a statement is made as above, for what period does the interest apply, the interest being one morning at 9% and in the afternoon dropping to 3%? What influx in bullion or accepted securities can account for such a drop in the rate of interest, assuming that market operations are on a rational basis?

Money is a commodity like anything else. There is a market for money, and there are brokers who deal exclusively in money. There are usually plenty of borrowers. Banks and financial institutions have what they call surplus money to loan from day to day. The rate is governed by the law of supply and demand.

In the morning it may appear as if there were a large demand for money and as if loanable funds would be scarce. As the day passes, the demand slackens or the supply becomes plentiful, or it may be just the opposite, and the rates fluctuate accordingly.

The term of the loan for such funds is until noon of the following day, and assuming that the collateral and the rate are satisfactory, the loan may be continued from day to day. If there has been a great change in the value of money, either up or down, the banker may hear of it in the first instance from the borrower, who fixes the rate high enough to insure his keeping the loan if he is needy, and must have it, or down to the lowest rate that he knows he can get the money for elsewhere.

THE ELECTRIC MOTOR IN THE SILK INDUSTRY

By Andrew Kidd, Jr.

It is only within the last few years that silk manufacturers in this country have realized the many advantages of installing electric motors in their mills. The system of transmitting power from the engine room by a belt or ropes to line shafting in the mill, the running of belts through ceilings to operate machinery on the floor above, and the conveying of power by means of shafting, belts or ropes from one building to another, is no longer considered by manufacturers who are contemplating the erection of a new mill or an addition to an old one.

While the cost of power is a small part of the total cost of finished silk, yet, with competition keen, the enterprising manufacturer will grasp every opportunity to reduce the cost per yard of his manufactured article, and the electric motor has assisted him materially in this respect.

The three methods of driving are:

Mechanically, by line shafting, belts or ropes;

Electrically, by grouping looms or preparatory machines under one motor; and,

Electrically, by an individual motor for each machine, particularly looms.

The old system of long line shaft drive, running the full length of the weaving room, and counter shafts driven from this main line shaft, as shown in Fig. 2, is a very inefficient means of transmitting power. One striking example of the extravagance of this system was recently called to the writer's attention. In an old mill an engine of 100 h.p. capacity was delivering power to looms and necessary preparatory machines. All looms and machines were stopped, and it was found that 42 h.p. was lost in transmission. This represents what is ordinarily termed "friction load," and is the power required to drive simply the shafting, belting and loose pulleys on the machines, when the machines themselves are idle. It is the friction load under this condition, but under this condition only, for as soon as the belts are shifted to the tight pulleys and the machines are placed in operation, this friction load is undoubtedly greatly increased. No method has as yet been devised to determine accurately the extent of this increase in the friction, but the fact remains and should never be lost sight of, that the friction load under operating conditions is greater than when the machinery is

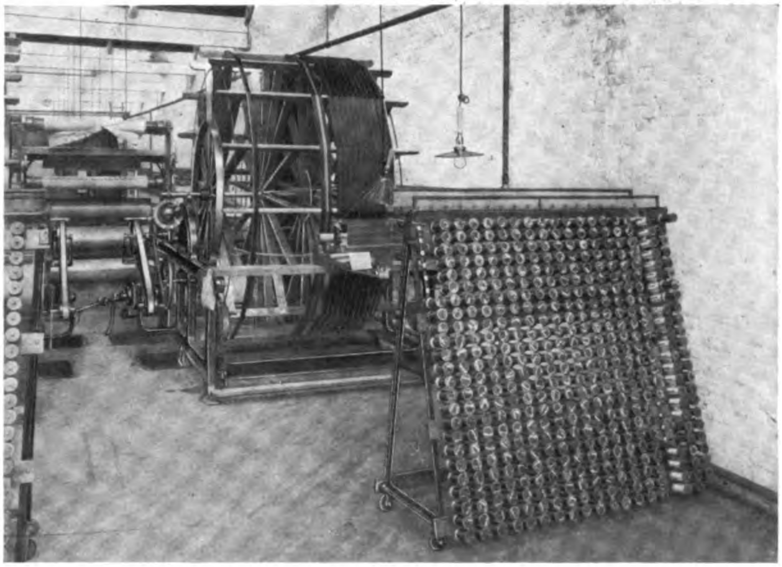


Fig. 1. Silk Warper Driven by General Electric KG 3/4 H. P. Motor

idle; and it is the power necessary to overcome this increased friction load that must be paid for by the manufacturer, and for which he receives no return. This loss gradually becomes worse as the belts stretch, shafts and pulleys become more and more out of alignment and the bearings wear.

In this system the maintenance items, such as cost of attendance, care and renewals of belts, oil, etc., are to be seriously considered. Then there is the liability of an accident to the shafting causing the whole, or a part of the mill to go out of commission, which accident would show up materially in the total output of finished product for the day or the week, depending upon the amount of repairs necessary.

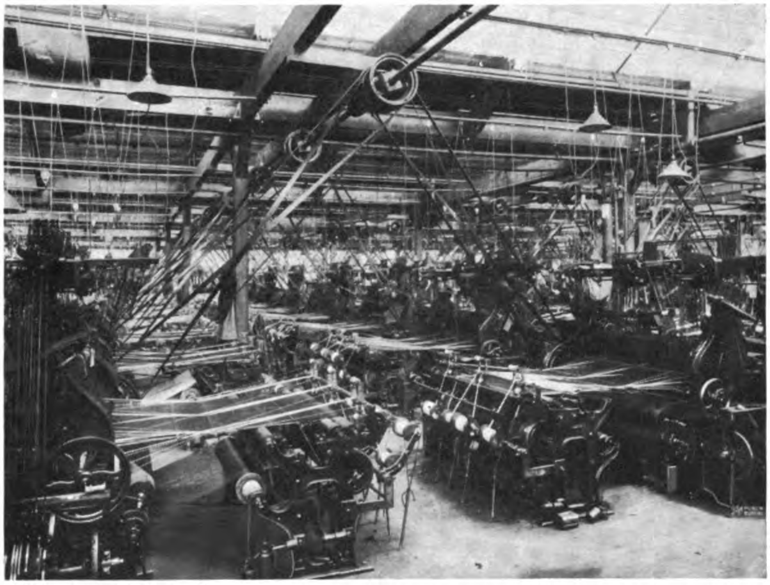


Fig. 2. Weaving Shed, Driven by Line Shafting and Belting, Showing Complication of Belts

There is also the ever-present danger of dripping oil falling upon the raw material or the finished product.

In the motor-driven mill, the first thing to be considered is whether the current is to be direct or alternating.

Under some conditions where the electric motor is used, a slight variation in speed is not objectionable; in fact for machine tools, printing presses and railway service a decided variation in speed is required, and under this condition the direct current motor is almost indispensible. However, inasmuch as the conditions in a silk mill demand constant speed a little consideration will show that the alternating current motor offers marked advantages.

If direct current is used, provision must be made to take care of the speed changes, which cannot be eliminated in the design of the motor. The reason for the variation in speed is that when the motor is started up, the field windings are cold and, consequently, their resistance is low, allowing an excess of current to flow through them. This excess of current tends to keep down the speed, and as the motor is being heated, say for three or four hours, the current slightly decreases, and the resistance and speed increase.

The speed of a 40 h.p. direct current motor will vary 7 per cent. during the time the motor is heating up. A loom operating at 120 picks per minute would start off each morning at 111 picks per minute and gradually increase the number as the speed increased, until the motor reached its normal temperature when the looms would operate at 120 picks per minute for the balance of the day.

In order to compensate for these changes a resistance box or rheostat must be inserted in the field circuit, and the strength of the field regulated frequently in such a manner as to keep the speed of the motor constant.

The speed of a direct current motor will also vary if the voltage on the circuit changes, which change sometimes happens when a heavy load is thrown on or off the generator in the power house.

With alternating current motors none of these difficulties are experienced. The speed of the motor does not vary when under constant load, but depends solely upon the speed of the engine which drives the generator. There are no brushes nor commutators, and no frictional parts, except the bearings; therefore, in comparing direct with alternating current motors, the latter should decidedly be given the preference for silk mills.

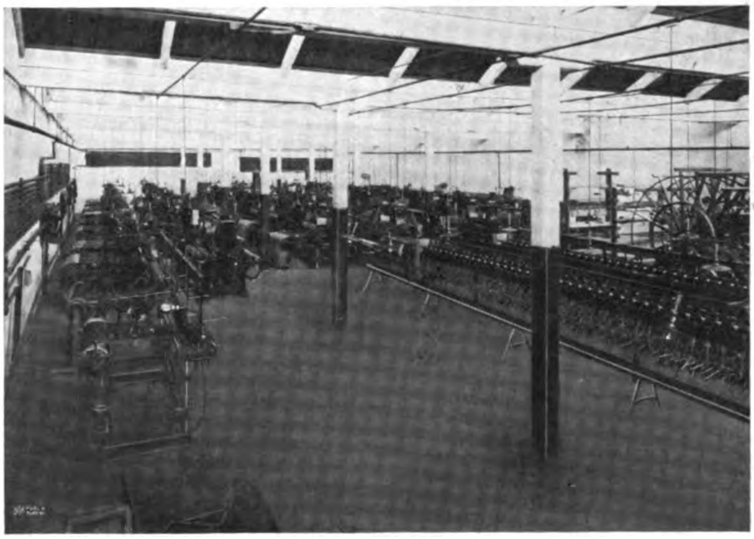


Fig. 3. Weaving Shed with Individual Drive, Showing Absence of Belts

The grouping of machines under one motor is looked upon favorably by many engineers and manufacturers, and very good results can be obtained from this system if particular attention is given to the arrangement of the shafting and the selection of the proper motor for the work to be performed. This system is used extensively where the machines being driven are run continuously, such as the preparatory machines used in a silk mill. The motor used should work up to its full capacity, in which case the highest economical efficiency is obtained.

A group of 48 in. looms, say 75 to 100 in number, can be driven by a 40 to 50 h.p. motor. As the torque required to start a loom is 100 per cent. above normal running torque, this size motor would be ample for operating these machines successfully, since it is unlikely that a sufficient number of the looms would be started at the same moment to load the motor beyond its overload capacity.

As in the case of the mechanical drive, the group system drives the shafting and belting continuously, whether one of the machines is in operation or all are. The efficiency is greatly improved with the group system, since a 75 kw. (100 h.p.) dynamo has a full load efficiency of 91 per cent. and a 50 h.p. motor has an efficiency of 89 per cent. Allowing a 3 per cent. loss in the line, this will give an efficiency of 78.5 per cent. from the engine shaft to the motor shaft. This group system has the advantage of greater flexibility than the mechanical system, due to the fact that any group may be run independently of another, and should a break-down occur the particular group involved would be the only part of the mill affected.

The production of the looms is greatly increased, as the slipping of the belts is confined to one section, which gives a more constant speed. By reason of this more constant speed, the wear and breakage on the loom and the work of the loom "fixer" is greatly reduced. All heavy line shafting, hanger bearings and heavy belts are eliminated.

The General Electric Company, within the last few years, has equipped several of the largest silk mills with individual motors direct connected to looms. This Company has done more work in this line than any other electrical concern in this country, having sold over 1500 motors for the driving of as many looms, for the weaving of silk, worsted and velvet. Wherever this individual drive has been tried it has always met with success, as its many advantages are soon brought to light.

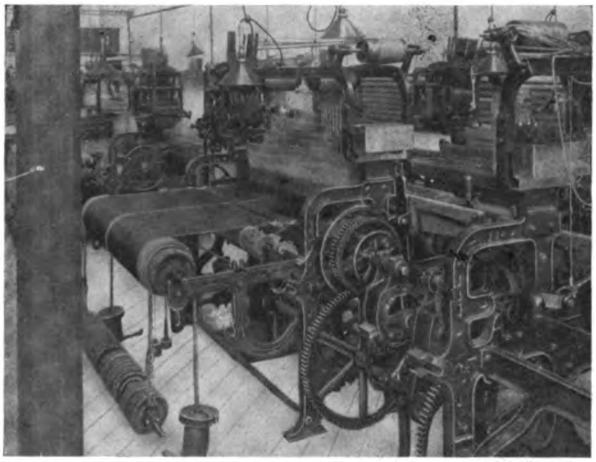


Fig 4. Side View of Crompton-Knowles Silk Loom Driven by General Electric KG 1/2 H. P. Motor

A direct current motor is not to be recommended in silk mills for individual drive, as it is uneconomical and unsatisfactory for the conditions existing in silk mill operation. Therefore, the following remarks apply to the alternating current motor.

The method of installation is very simple, and is, in the majority of cases, entirely successful. In place of the belt pulleys used on mechanically-driven looms, and the friction clutch pulleys also used on such looms (and also advocated by some supporters of the individual electric drive), there is mounted a gear which meshes into the motor pinion. This gear is equipped with a special device, the duty of which is to protect the loom from excessive shock when the loom "bangs off," and which provides the same degree of elasticity as is obtained through the slipping of the belt and by the friction disc pulley ordinarily provided. A bracket bolted to the frame of the loom supports the motor. This bracket is so arranged that a vertical motion of the motor is allowed, as the different speeds of the loom are obtained by changing the motor pinion. The motor may also be supported from the jack shaft of the loom, in which case an eccentric bushing is provided which keeps the motor in perfect alignment and allows for the vertical movement necessary for changing the pinion. In all cases the motor is held to the loom in a very substantial and rigid manner.

It is generally preferable to stop the motor with the loom, thus saving all unnecessary losses and reducing the wear on the motor and its connections to the loom.

An oil switch is furnished with this equipment, and is held to the frame of the loom and connected to the shipper handle in such a manner that the weaver, to operate the loom, starts the motor instead of shifting the belt. The friction gear referred to in the preceding paragraph permits this to be done without damage to the machinery or to the fabric in the loom.

By any method of driving, either electrical or mechanical, that employs shafting and belting, certain losses appear at all times, due to friction and the slipping of belts, whether the looms are idle or in operation. These losses are eliminated entirely by the individual drive, as this arrangement requires energy only when actual production is being carried on.

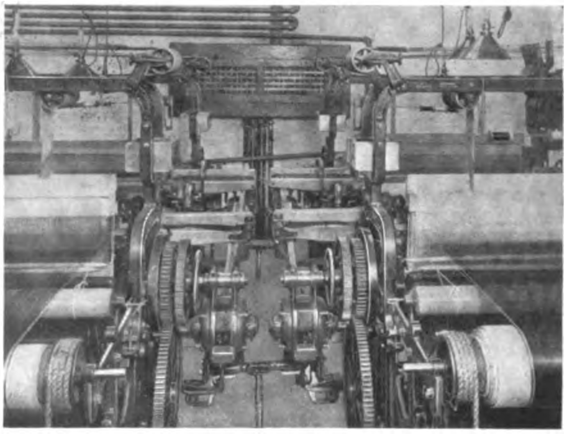


Fig. 5. Group of General Electric KG 1/2 H. P. Motors Driving Crompton-Knowles Silk Looms. Distribution Board in Rear.

The most beneficial result of the individual drive is the increased production. This is conservatively figured at 5 per cent., and is entirely due to the constant speed of the loom owing to the absence of all belts.

The maintenance item is reduced to a minimum, since there are no belts, line shafting or hanger bearings to be considered, the only frictional parts of the equipment being the motor bearings and gearing. The repairs on the loom are very much less for the group drive than for the mechanical system, and much less on the individual drive than on either. This installation is ideal, inasmuch as the looms may be placed to the best advantage for light, regardless of location to the generating plant. There is no dirt or oil overhead, and the pulleys and belts, which continually stir up dust through the atmosphere, are no longer required.

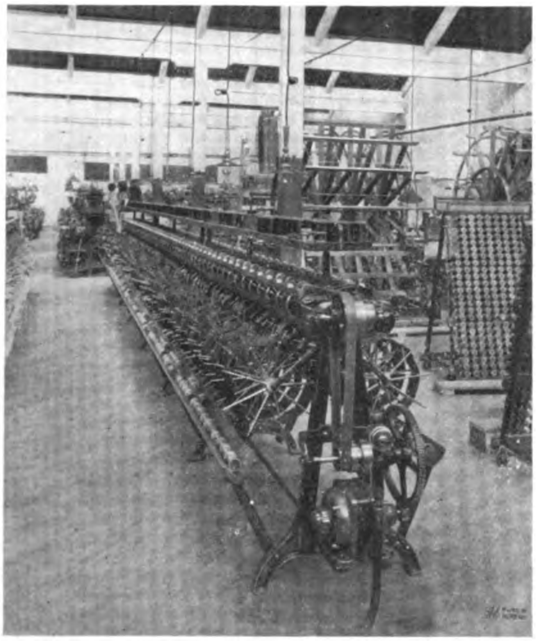


Fig. 6. Silk Winder Driven by General Electric KG 1/2 H. P. Motor

The first cost of installation for the individual drive is somewhat more than for the group drive, but when the increased production, decreased maintenance, unrestricted light, and the absence of all dirt and dust, are taken into consideration, the manufacturer will agree that he will very soon be fully reimbursed for the extra expense incurred.

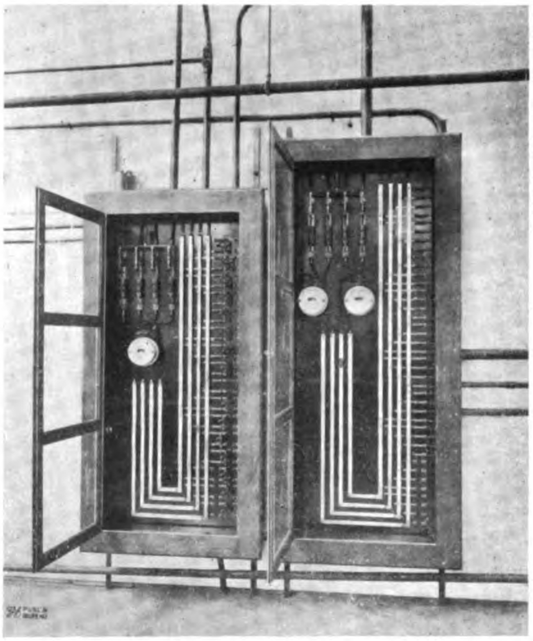


Fig. 7. Main Distribution Cabinets. Lighting Panel on the Left, Power Panel on the Right

The accompanying photographs were taken at the Empire Silk Company's plant at Wilkesbarre, Pa., and show one of the recent installations of this system where no line shafting or belts are employed, as each loom, warper, quiller and winder is driven by its own individual motor. The looms were purchased from the Crompton-Knowles Company and the motors from the General Electric Company.

GEOLOGY OF JAMAICA *

By Rossiter W. Raymond, Ph. D.
Secretary of American Institute of Mining Engineers

I did not use this subject because I wished to teach the geology of Jamaica, for I am going to say very little about it and I shall mention only enough to introduce the real subject, which is not the geology of Jamaica but the history as controlled by the geology. The subject of the controlling influence of the natural environment upon the history of man is the opposite to the subject of man's effect upon the environment. Thirty odd years ago a great book, called "Man and Nature," was written on that subject by George T. Marsh, a book I hope all will read who have not already done so

I have never seen or heard of a better or more striking illustration of the effect of geology on history than that afforded by the Island of Jamaica; where I spent some time about a year ago. The geology of the Island has been very admirably described by Mr. Robert R. Hill, an American geologist, and if the reader wishes to go into details I would refer him to this account.

The shores of the Gulf of Mexico, taken together with the islands constituting the Greater and Lesser Antilles and Leeward Islands, form what Mr. Hill calls the American Mediterranean. The Caribbean Sea is a part of this group, and is shut off by chains of islands and by the solid mainland of the continent from other portions of the Atlantic Ocean. In the middle of the sea rises a steep peak of a mountain range. This peak is Jamaica.

The water is very deep at some points along the coast, and even this has had a curious effect upon the history of the island's geology, because geologists could not identify the rocks with those of other islands. The water here is so deep that shallow water specimens can not live beneath it, and therefore fossils which are present on other islands are absent on the coast of Jamaica.

Planter's Residence, Oxford Penn

The Island of Jamaica is about 145 miles long and 45 miles across in the widest place, and consists principally of an upheaval, the highest point being about 7400 ft. above the sea level, which is quite a height to look up to. There are, of course, points in the Rocky Mountains much higher than this, but due to

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* Lecture delivered before the Schenectady Section, A.I.E.E. January 25, 1908.

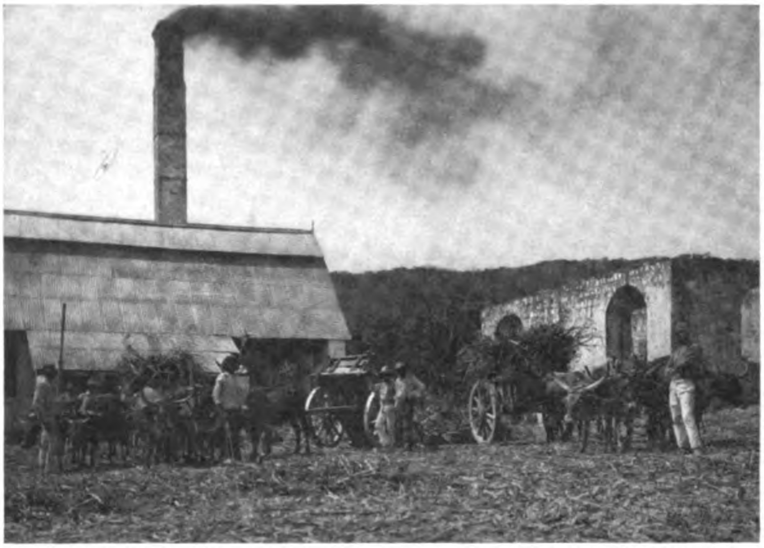
the altitude of the surrounding country, the apparent distance up is less than is the case with Jamaica.

One of the peculiarities of the scenery is that it combines the sublimity of the Andes with imitation of glaciers, with the canyons of the Rocky Mountains, and with the tropics thrown in, clothed with luxuriant vegetation.

The summits, subjected to the tropical torrential rains, are sharply accentuated. The general topography, or at least the upper part, is illustrated by the story of Columbus crumpling up a handkerchief, and saying "It looks like that." A little further down, 2500 ft. above the level of the sea, is another and later formation. This is a horizontal plateau of limestone which surrounds the central core as if it were a ruffle around the neck of Queen Elizabeth, the mountains rising from the middle. This plateau of limestone has peculiar formations in the nature of "cockpits," which are great funnels 250 to 500 ft. deep in which the water of the heavy rains disappears, and no doubt drains through the limestone rock to the underlying core. At the edge, this limestone plateau breaks off into bluffs, 100 to 200 ft. high. Below these are the lowlands of the coast on which lies the debris of the bluffs consisting of graveled limestone such as is found along the coasts of the other islands. Along the edge is a series of navigable bays.

That is all of the geology I am going to give, and it will be seen how these features have illuminated and foreordained every chapter in the history of the island.

No gold has been found in Jamaica, which fact is rather remarkable considering that Cuba has gold, San Domingo has gold, and the mainland opposite is a very treasure house. If the Spaniards did not find gold in Jamaica, the island gave them something else; namely, those bays that I have told you of, which became the lurking places of the buccaneers, who ran into them and hid. Kingston, or the locality near it, was the great commercial center or metropolis of the whole of the Spanish seas, where the buccaneers came and sold their plunder, bought what they wanted, lived riotously, got supplies, made repairs, and were off again. Now buccaneering is not legitimate commerce, but it is commerce just the same, and after the lawlessness got knocked out, the commerce remained; so from that day to this the towns of Kingston and Port Antonio, and some of the other ports in Jamaica, have been the very centers of the great West Indian trade. They will be even more prominent in this respect when our Panama Canal is finished, for Jamaica is just off the Panama Canal, and there will then be more trade than ever.



Bringing in Sugar Cane to Mill House

One of the most important results of this great commerce was that the ships which entered the harbors of Jamaica during all these times of the buccaneers and the subsequent West Indian trade brought with them, sometimes voluntarily and sometimes involuntarily, seeds of new plants and trees, varieties of animals and livestock, straw, manure, and all sorts of things which might easily bring forth new vegetation in a new country. So, first of all, it came to pass as a result of this commerce that new growths began to flourish, and the outcome to-day is that Jamaica is a country in which nearly everything that we consider characteristic of the country is exotic, and was imported there. I have a little memorandum which states that when Columbus was sitting in his mouldering ship in the bay, there was in Jamaica no sugar cane, bamboo, oranges, lemons, limes, citron, grape fruit, coffee, kola, cinnamon, rice, bread fruit, bananas, cocoanuts, etc., although there is some doubt as to whether cocoanuts should be included in the list.

East India Coolies at Their Midday Meal

Essentially, the whole flora which now covers the island of Jamaica has been imported. All the animals, the fauna as well as the flora, come under this head. There is not a single living animal in Jamaica of the kind that was there when Columbus discovered it, except perhaps the cony, which is scarce, but which is said to be seen occasionally among the rocks. All the other animals of Jamaica have been imported, even to the mongoose, which was brought in to fight the rat, this latter pest having found its way there in the ships. When the mongoose arrived it killed the birds as well as the rats; the birds are consequently very much scattered, and the inhabitants are fighting the mongoose to exterminate the species.

Not only have the plants and the animals been imported, but the men also. The original Caribs appear to have been very peaceful, and although they may have eaten one another occasionally, nevertheless they were very gentle. If they were cannibals, they were so simply for the same reason that has made cannibals of many other tribes—a superstitious belief that they might increase their courage by eating the heart and drinking the blood of brave men.

The Spaniards, not having found gold in Jamaica, and not at first having brought the sugar cane and started its cultivation, which required labor, captured the Caribs and sent them off to be peons and laborers in gold mines, and in that way the race absolutely disappeared. I do not believe there is a trace of them left on the island. Then, as the Spaniards afterwards needed laborers for the cultivation of sugar cane, etc., they brought slaves from Africa. Do not let us make the mistake of thinking Africa a small country and every native just like our negroes. East Africans, West Africans, South Africans and Ethiopians are as different as different races in other countries, and one of the first things which strikes one in reading and studying the history of Jamaica is this difference of races among Africans. The Spaniards brought over a lot of African slaves who sprung from a very different race from those England brought over afterwards.

View of Mountain Village

In the time of Oliver Cromwell, an expedition was sent out to capture some certain island; the expedition lost its way and captured Jamaica from the Spaniards instead. The Spaniards did not fight long, but they did a crafty thing. They called together the African slaves and gave them their freedom, taking from them a promise that they would never be slaves to anyone else and would never surrender. These freed slaves of the Spaniards received the English afterwards very much after the fashion of the guerrilla warriors of Spain. They retreated from the coast, which was generally inhabited for commercial reasons by the whites, to the limestone plateau and into those cockpits, filled, you must imagine, with dense vegetation. I have traveled through some of those jungles and gone through their villages without seeing any people, everyone being hidden in the dense vegetation of the trackless jungles. These people are called Maroons, the word Maroon being a corruption of a Spanish word signifying outcast. These Maroons, as I have said, retreated to the high land, where they were concealed in their mountain fastnesses, and from which they descended from time to time to raid the settlements below. These settlements gradually became a very active sugar-producing colony of England, and the English brought negroes there to work. These slaves were negroes from Africa, but not of the same race as the Maroons. The proud Maroons, who had never been slaves to any country but glorious Spain, hated and despised other kinds of negroes. It is very curious that these people actually were proud that they had been slaves to Spain but never to England. The cockpits gave them another world as it were, from that on the coast; a world in which they could retreat, manœuvre and hide forever, making it almost impossible for the English to deal with them. These slaves and their descendants kept up a fierce war with England for 150 years. Expedition after expedition was armed and sent out to overcome them, but never came back. The English were trapped, ambushed and massacred, no one living to tell the story. At last, in 1738, an English general managed, not to conquer the Maroons, for they were never conquered, but to get them still long enough to hear what he had to say, and negotiated a treaty. As the Indian tribes in our country have been treated as independent, so the Maroons were treated by the proud kingdom of Great Britain as independent, and a treaty was made by which they became allies of the English. After that, as they were friendly, it did not make so much difference about their living in the cockpits and jungles up on the limestone plateau. They came down occasionally to trade, and the governor would go up once a year probably, blow his horn and call them together and issue some sort of rations to keep them good natured.

Loading Banana Steamer from Lighters, Annoto Bay

On the Way to Market

About the year 1830 slavery was abolished in Jamaica. The result was disastrous to the island, not because slavery ought not to be abolished, but because its abolishment destroyed the plantation system of labor in Jamaica. The negroes, having their freedom, wanted to exercise it, as did our negroes after the war, by realizing their right to move about from place to place. The negroes in Jamaica were greatly encouraged in restlessness and indolence by the fact that a very little work goes a long way in that island for the support of a family. Negroes do not need much to eat, or many clothes, and nothing more in the way of a house than a roof; consequently a man with limited breeches and an umbrella could get along first-rate in Jamaica. On the other hand, about thirty days' work now and then was enough to raise in abundance whatever was needed. The plantations fell into neglect, and the negroes congregated in idleness and lived with little concern because there was little required of them by the climate. By and by they began to be restless and discontented, and in 1865 the terrible rebellion broke out in Jamaica, concerning which so much has been said and written. The older people will remember how the governor was criticized for the course he pursued, by Huxley, Spencer, Gladstone and others, while on the other hand, another party was equally strong in his defense. I can see that Governor Eyre did what was necessary, and that without his swift, sharp and even cruel action, the rising would have resulted in the massacre of the entire white population, which was only 3 per cent. of the total, the other 97 per cent. being negroes. There was one massacre—some of these tribes arose and killed all the whites in one town, creating a tremendous panic. The governor made reprisals which were awful, but the most terrible thing he did was probably largely unintentional at the time. He called upon allies whom he was afterwards unable to control—the Maroons up on the limestone plateau. He sent to them to come down and attack the others; and these men, resting in idleness and dreaming of the old days, woke up, sounded their battle cry again, and descended. The horrors of what they did to the blacks constituted the chief charge against Governor Eyre. He did not intend that the Maroons should do all that they did. He could not control them. After slaughtering right and left, and plundering until they were tired, they retired to their abodes on the plateau, and have hardly been heard of since. This was nearly fifty years ago.

H.M. Mails and Post Office

There is one more race to be mentioned to complete this collection which has been imported to Jamaica; namely, the Hindoos. Ten or fifteen thousand of these coolies were brought over from East India on time contracts. The cost of transportation was taken out of their wages, and when their time was out they had the option of going home or staying on the island, and many of them stayed. The color of their skin is an attractive black—not a dense black—and they possess straight noses and thin lips. They are lithe and slender, with small hands and feet, and dress in white suits, with wrappings rather than trousers to the knee, scarlet jacket and turban; and as you go along the roads and meet them they give you a greeting of good morning or good afternoon, with an oriental salaam. Small as they are physically, they are very good laborers. They bring their wives and children out with them, and load the women with jewelry. The men are good silversmiths, and as you walk along you see the women with their curious silver ornaments, necklets, bracelets, chains, etc., and you can buy anything they have on. This is the way they exhibit their wares, and the next morning they will be out with a fresh supply.

Another thing with which the geology has had much to do is the great variety of climate. There are different climates at different elevations and on different sides of the island. The bananas and cocoanut palms require plenty of water, and are found in the lower regions, while further up are the coffee plantations.

The Government has established a most wonderful garden for the promotion of agriculture, and tries the raising of plants from all parts of the earth, those that are suitable for the climate and soil being propagated. Practically everything will grow in Jamaica.

The government of Jamaica built a railroad which crosses the island, and which goes through 28 tunnels in 30 miles. It does not pay. It is too long, and it is too expensive for the chief products, such as bananas and cocoanuts. The United Fruit Company do a great banana business, and have 65 steamers of two or three thousand tons running all the time between Jamaica and the United States, and the way they get their cargoes is thus: The steamer will go to the principal headquarters, Kingston, Port Antonio, etc., and unload; it then sails around the island and into the different bays, and as the steamer comes in the banana growers are found waiting with their product. It is not more than ten or twelve miles from any banana plantation in Jamaica to the ocean. The United Fruit Company also sends carts through the island to gather up the fruit for market, and if a negro wants a little money he takes a bunch of bananas and sits down by the side of the road and waits for the cart to come along. The driver takes the bunch of bananas and the negro a copper check good for money. The result is that small producers have a way of getting what money they require without a great deal of trouble. It is pretty hard to arouse the negroes in the present generation to a state of excited ambition—they are too comfortable. I do not suppose there is another country in the world where one class of labor will look on complacently while another class steps in and takes its work. The Jamaican negro to-day looks with the utmost pleasure and complacency upon the East Indian coolie who has come over to do the work he did not like. The whole race, in fact, has something of that attitude—the consequence of their climate.

Although the present condition of Jamaica is not wholly prosperous, the conditions for prosperity are there. The new life of Jamaica, as we call it, has been brought about by the geology. The negroes of Jamaica to-day are supplied, through the commerce of the United Fruit Co., with the opportunity to make money, and the children are showing signs of real ambition to better their condition. I found a few cases of black men who have got rich, and it is possible for any one of them to save money if he has the desire to do so. The Government of Jamaica has started primary schools in great numbers.

The geology of Jamaica has produced this wonderful variety of climate, and has filled Jamaica not only with tourists, but also with products that will restore her wealth in a much more healthy and beneficial manner than that brought about in the days of the buccaneers or the Jamaican slave owners. Besides the public schools there are technical schools and a university, and from this university any man of sufficient ability is eligible for the Rhodes scholarship at Oxford, England, and some of these men have taken it already. The next best thing to good schools which the government can furnish toward civilizing and elevating the people is good roads. This little island has 4000 miles of roads as good as we can furnish in any of our parks. They are made of the limestone from the coast, and wherever you go you see little piles of stone waiting to be reduced to the ordinary size for macadamizing. When one of the natives wants to earn a little money he sits down and breaks stone, and when a certain amount has been broken the inspector gives him a ticket for that amount.

Geological Formation on South Coast. Coral

ROTARY CONVERTERS

PART IV.

BY ERNST J. BERG

Heating of Rotary Converters when supplying Unbalanced Load in a Three Wire System, the Neutral being derived from the Transformers

As a limiting case it will be assumed that full load direct current is supplied from one side of the three-wire system only; one brush therefore carries full load current, the other no current.

In this case the direct current output is one-half of what it would be with balanced load, and the maximum value of the alternating current will be one-half the value determined for the case of heating considered in the first part of the discussion. In that particular instance a direct current of 2 was considered, and the corresponding maximum values of the alternating current were:

2 for the single-phase converter.
1.54 " " three- " "
1.414 " " four- " "
1.33 " " six- " "

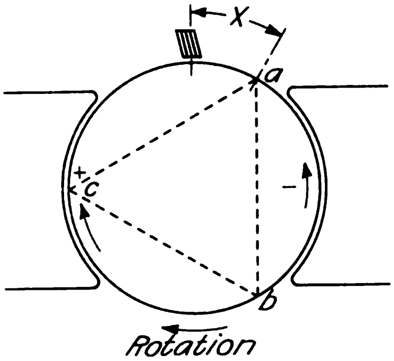


Fig. 14

In this case, therefore, the maximum value of the alternating current in the winding is:

1 for the single-phase converter.
0.77 " " three- " "
0.707 " " four- " "
0.665 " " six- " "

In the analysis given below the three-phase converter is considered.

The circuit of the direct current is from the brush to the line, then to the neutral of the transformers, returning to the brush over the three lines *a*, *b*, *c*, and the winding between the brush and *a*, *b*, *c*.

One-third of the line current enters through each of the three lines *a*, *b*, *c*. In each case the current can enter the brush by two paths in parallel, and the proportion of the current in each will depend upon the resistance of the path.

Assume as before that the armature has 48 slots, and denote the position shown in Fig. 14 as No. 1; the resultant current in phase *ab* will be determined for each 7.5 degrees revolution. A current flowing clockwise will be considered as positive, and counter-clockwise as negative, as indicated in the figure. The current in *a* enters the brush in a negative direction over the coils x (in this case $x = 4$), and in a positive direction over coils $48 - x$. Therefore, the current will divide as

$$\frac{48-x}{48} \text{ is to } \frac{x}{48}.$$

The positive current is $\frac{x}{48} \times \frac{2c}{3}$,

and the negative current is $\frac{48-x}{48} \times \frac{2c}{3}$,

or for $c = 1$

$$a_- = \frac{48-x}{48} \times 2/3$$

$$a_+ = \frac{2}{3} \times \frac{x}{48}$$

In a similar way we find that

$$b_- = \frac{32-x}{48} \times 2/3$$

$$b_+ = \frac{16+x}{48} \times 2/3$$

and $$c_- = \frac{16-x}{48} \times 2/3$$

$$c_+ = \frac{32+x}{48} \times 2/3$$

In section *a b* we have a resultant direct current of the negative currents of *c* and *b*,

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Errata. In the third section of this article, which appeared in the March issue of the REVIEW, Figs. 1, 2, 3, 4 and 5 should have been numbered 9, 10, 11, 12 and 13, respectively.

and the positive current of *a*. Thus the resultant direct current c_0 is:

$$c_0 = -\frac{(16-x)\,2/3}{48} - \frac{(32-x)\,2/3}{48} + \frac{x\ 2/3}{48}$$

$$= -\frac{16-x}{24}$$

This equation gives the following values to c_0 for the positions listed:

Position	x	c_0	Position	x	c_0
No. 1	4	−0.5	No. 15	18	+0.083
2	5	−0.46	16	19	+0.125
3	6	−0.417	17	20	+0.166
4	7	−0.373	18	21	+0.208
5	8	−0.333	19	22	+0.25
6	9	−0.292	20	23	+0.292
7	10	−0.25	21	24	+0.333
8	11	−0.208	22	25	+0.373
9	12	−0.166	23	26	+0.417
10	13	−0.125	24	27	+0.46
11	14	−0.083	25	28	+0.5
12	15	−0.0417	26	29	+0.54
13	16	−0.	27	30	+0.582
14	17	+0.047			

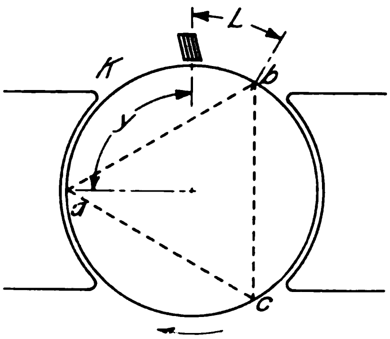


Fig. 15

When the armature has turned more than 28×7½ degrees, or 210 degrees, each section of phase *a b* carries a different value of current, as may be seen from Fig. 15.

Under these conditions we have:

$$a_+ = \frac{48-y}{48} \times 2/3$$

$$a_- = \frac{y}{48} \times 2/3$$

$$b_+ = \frac{16-y}{48} \times 2/3$$

$$b_- = \frac{32+y}{48} \times 2/3$$

$$c_+ = \frac{32-y}{48} \times 2/3$$

$$c_- = \frac{16+y}{48} \times 2/3$$

Section *K* carries all positive currents, and section *L* all negative currents.

Thus c_0 in $K = \dfrac{32-y}{24}$

and c_0 in $L = -\dfrac{16+y}{24}$

which give the following values to c_0 for sections *K* and *L*, for positions 29 to 45, inclusive:

Position	y	K	L
No. 29	16	0.66	−1.33
30	15	0.707	−1.29
31	14	0.75	−1.25
32	13	0.79	−1.21
33	12	0.834	−1.16
34	11	0.875	−1.12
35	10	0.917	−1.08
36	9	0.96	−1.04
37	8	1.00	−1.
38	7	1.04	−0.96
39	6	1.08	−0.917
40	5	1.12	−0.875
41	4	1.165	−0.834
42	3	1.21	−0.79
43	2	1.25	−0.75
44	1	1.29	−0.707
45	0	1.33	−0.66

For the remaining position we can again use the first equations, since all coils in phase *a b* carry the same direct current; thus

$$c_0 = -\frac{16-x}{24}$$

Position	x	c_0
No. 46	1	−0.625
47	2	−0.583
48	3	−0.54

The instantaneous value of the alternating current for any position is:

$I = 0.77 \cos \phi$, where $\phi = 0$ for the first position, and each successive value of ϕ corresponds to 7.5°.

Thus, for instance, the heating which is proportional to the square of the current is in position No. 8, which is determined as follows:

$C_0 = -0.208 \quad I = 0.77 \cos (7\times 7.5°) = 0.468$

Resultant current = 0.26

and current^2 = 0.0678.

These calculations are carried out for each coil and position, and the results are:

For a three-phase rotary converter with only one side loaded, 70 per cent. of the rated output can be carried. For a four-phase and a six-phase rotary, 73 and 77 per cent., respectively, of the rated output can be carried at one-half voltage.

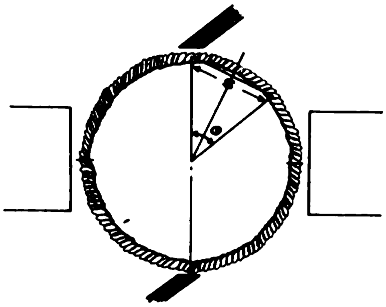


Fig. 16

In other words, the current going out from one of the brushes and back over the neutral can, in the first case, be 40 per cent. greater than the normal full load, and in the last case 54 per cent. greater.

Armature Reaction in Rotary Converters

Sometimes the total magnetomotive force of the armature is considered as armature reaction, often as the resultant magnetomotive force per pole, and most frequently as the product of the direct current in the conductor and the number of turns per pole in the armature.

In the following discussion the armature reaction is taken as the resultant magnetomotive force of the armature per pole.

It may be expressed as

$$R = \sqrt{2}\, k\, k_1\, i\, t$$

where k and k_1 are constants, depending upon the system considered and upon the distribution of winding, respectively; i the effective value of the alternating current, and t the number of armature turns per pole and phase. With direct current, where the winding is uniformly distributed, k_1 is the ratio of the diameter to one-half of the circumference, or $\frac{2}{\pi}$; and k is unity.

In an n-phase closed circuit alternator (Fig. 16), run as a rotary converter, k_1 becomes

$$\frac{S}{2\pi r} \div \frac{360}{\phi} = \frac{360\, S}{2\pi r\phi} =$$

$$\frac{360\times 2r}{2\pi r\phi}.\sin\frac{\phi}{2} = \frac{360}{\pi\phi}\sin\frac{\phi}{2}$$

ϕ is obviously $= \frac{360}{n}$

thus $k_1 = \frac{n}{\pi}\,.\,\sin\frac{180}{n}$

k, as stated above, depends upon the system, and gives the relation between the resultant armature reaction of all phases and the armature reaction of one phase.

In an n-phase machine, the windings of the respective phases are displaced $\frac{360°}{n}$; thus, at a given time, the currents a, b, c, etc. (Fig. 17), are expressed as:

$$I, I\cos\frac{360}{n}, I\cos\frac{2\times 360}{n} \;....\; I\cos(n-1)\frac{360}{n}$$

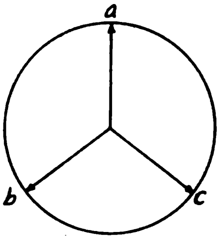


Fig. 17

Each of these currents has a component in phase with I, which is the product of the current and the cosine of the angle; thus the combined magnetomotive force of all phases is:

$$I\cos 0 + I\cos^2\frac{360}{n} + I\cos^2\frac{2\times 360}{n} +$$

$$....\; I\cos^2(n-1)\frac{360}{n}$$

$$\text{Thus } k = \frac{\text{combined magnetomotive force}}{I}$$

$$= \cos 0 + \cos^2\frac{360}{n} + \cos^2\frac{2\times 360}{n} + \;....$$

$+ \cos^2 \frac{n-1}{n} 360$, to n terms, n being the number of phases.

In a single-phase converter where $n = 1$, we thus get $k = \cos 0 = 1$.

In a three-phase machine ($n = 3$), k becomes $1 + \frac{1}{4} + \frac{1}{4} = 1.5$.

In a similar way, for a four-phase machine $k = 2$, and in a six-phase machine $k = 3$. In general $k = \frac{n}{2}$.

It has previously been shown that the relation between the effective value of the alternating current and the direct current in a conductor is:

$$\frac{i}{i_c} = \frac{2\sqrt{2}}{m \sin \frac{180}{m}}$$

Considering a bipolar machine for the sake of simplicity, and denoting the direct current output by i, we get $i_c = 0.5\, i_d$

$$\text{thus } \frac{i}{i_d} = \frac{\sqrt{2}}{m \sin \frac{180}{m}} \qquad (7)$$

With t turns per pole, the number of turns per pole and phase are $\frac{t}{n}$.

Substituting these constants in equation

$$R = \sqrt{2}\, k\, k_1\, i\, t$$

we get the alternating current armature reaction

$$R_a = \sqrt{2} \times \frac{n}{\pi} \sin \frac{180}{n} \times \frac{n}{2} \times \frac{\sqrt{2}}{m \sin \frac{180}{m}}\, i_d \frac{t}{n}$$

Since in a multi-phase converter the number of phases n is the same as the number of collector rings m we get:

$$R_a = \frac{i_d t}{\pi}$$

The direct current armature reaction R_d is:

$$\frac{2}{\pi} \times \frac{i_d}{2} t = i_d \frac{t}{\pi} \qquad (8)$$

It is therefore proven that the true armature reaction is the same for direct current and multiphase alternating current, no matter how many collector rings there may be.

(To be continued)

STORE LIGHTING WITH ENCLOSED ARC LAMPS

By G. H. Stickney

The purpose of a store is to sell merchandise, and the purpose of artificial store lighting is to promote the sales. That arrangement of store lighting is the most satisfactory which produces the greatest margin of profitable sales over the cost of illumination.

Artificial lighting contributes towards the satisfactory sale of merchandise in the following ways:

1. By helping to make the store attractive and pleasant for customers.
2. By displaying the merchandise to advantage, so that the customer may be induced to purchase.

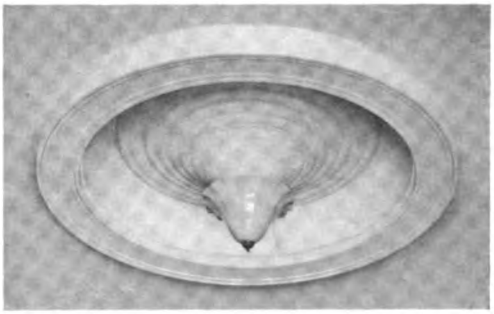


Fig. 1 Ceiling Diffuser

3. By showing the merchandise approximately as it will be seen afterwards, so as to avoid disappointment, especially where color selection is involved.
4. By making the store attractive and healthful for the employees.

Appearance of the Store

It is unquestionably true that on entering certain stores, the customer is agreeably impressed, and the store becomes at once attractive to him, while in certain other stores, an opposite or unpleasant impression is received, resulting often in a large loss of business. While there are many elements, more or less concrete, which go towards influencing customers favorably or unfavorably, we are interested in them in this discussion only so far as they relate to the artificial lighting of the room.

It is evident that an artistically arranged store will be more pleasing than one which is

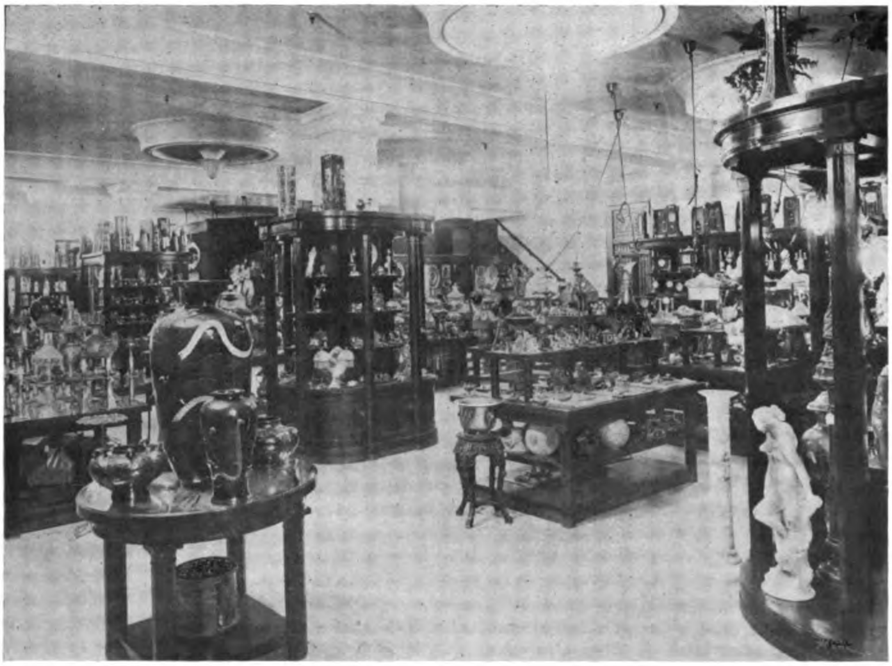


Fig. 2. Interior View of John G. Meyers Co.'s Store, Albany, N. Y., Lighted by Selective Ceiling Diffuser System

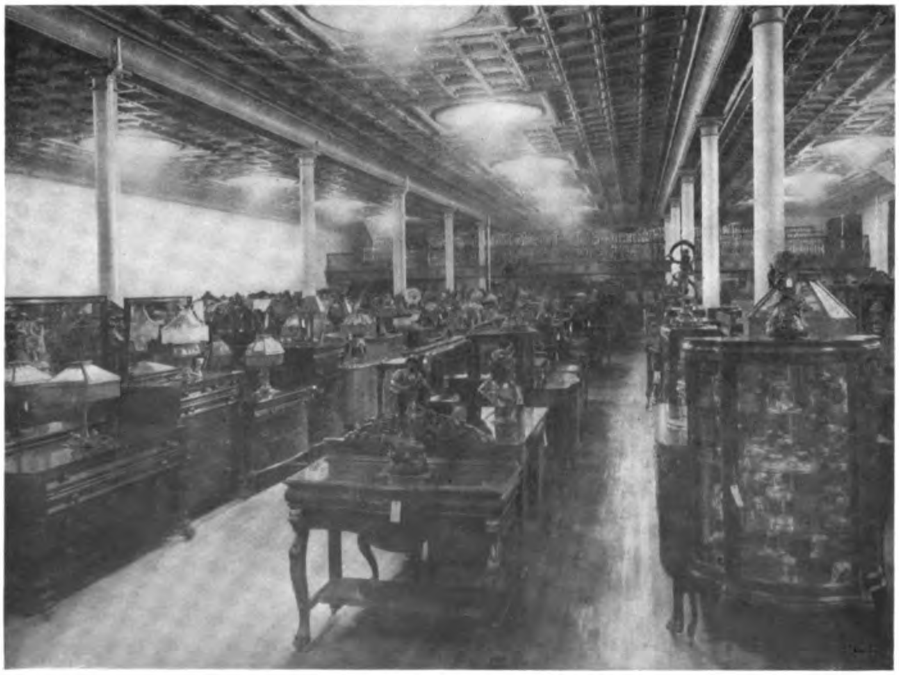


Fig. 3. Interior Fraas & Miller Store, Brooklyn, N. Y., Lighted by Selective Ceiling Diffuser System

disorderly and which lacks design, and therefore the lighting fixtures should, as far as practicable, conform to the general tone of the surroundings.

Usually, the lighting fixtures are more conspicuous as fixtures by daylight than by their own light, and their appearance in the store in daylight should therefore be considered. Where the lighting fixtures are of a stock pattern, it is especially desirable that they should be simple, and as inconspicuous as possible.

To a certain extent, some proportion should exist between the size and height of the room and the size and capacity of the lighting units. In a large room a comparatively small number of large units generally appears to better advantage than a large number of small units. Such an arrangement also gives life and character to the illumination. In a small or low room, a relatively small unit is preferable, for the sake of appearance as well as for the effective distribution of light.

Most people prefer a bright, cheerful store to a dark and dingy one, and experience shows that, as a rule, the bright store gets the business.

Lamps of high intrinsic brilliancy, when hung low, produce a blinding effect which is not only annoying and tiring, but which makes it difficult to view the merchandise satisfactorily. Even with sufficient light on the counters, if there is no light on the ceiling, the store is likely to appear dark and dingy. The light itself should be steady and approximately white. Colored lights do not mix effectually with daylight, and when a considerable portion of the light is to be thus mixed, it is desirable that the artificial lights should be as nearly white as possible. We may therefore conclude that a store can most easily be rendered attractive, as far as the lighting is concerned, by the use of simple, inconspicuous fixtures, with units of a capacity well proportioned to the size of the room; the light sources being high and of relatively low intrinsic brilliancy and so arranged as to distribute a soft, even and approximately white light throughout the store.

Lighting of Merchandise

A person's attention is usually attracted to the point of strongest illumination, and for this reason it is desirable that the merchandise displayed should have a relatively strong illumination compared with that of other parts of the room. This illumination should be fairly uniform, rather than spotted, so that the area for the effective display of goods may be as large as possible. Especially should harsh lighting and dense shadows be avoided.

Where colored materials require accurate selection in order to match some particular material or to produce some particular color effect, it is very important that the light be of the proper color. Many disappointments on the part of customers are due to a lack of proper attention to color considerations in the lighting of stores. The annoyance and inconvenience caused the customer may frequently be of greater moment than the value of the material itself. Since the larger part of the goods sold in a store is ordinarily used and seen by daylight, the store light should approximate daylight as nearly as possible. On the other hand, there are materials which are intended to be used principally in the evening, and consequently under a yellow tinted light. Means should therefore be provided for exhibiting this class of materials under such a light, and is ordinarily accomplished by providing an "evening room." The strong white light, while it shows up a fine material to its best advantage, also shows up the defects and imperfections of low grade material. On this account, it is observed that a poor illumination is usually preferred in a store where inferior materials are displayed.

Cheerful and accommodating attendants constitute one of the most important elements in the art of drawing trade to a store. Since each customer spends a relatively short time in a store he may be unaffected by lighting, which, to the clerks, may become almost unbearable. The ill effects of poor illumination in producing headaches and other discomforts is too well known to require any discussion. It therefore frequently happens that the comfort of the employee sets a higher standard upon the production of a fine soft illumination than do the requirements of the customers.

Economy

Store lighting would present much simpler problems if it were not for the necessity of giving so much consideration to the cost.

It is not particularly difficult to provide a strong, even illumination if it is permissible to consume an abundance of power and distribute the light through sufficiently dense globes.

It is not the first cost which requires the most serious consideration, but the after expense of operating. It is neither good engineering nor good business to burden a store with a running expense for illumination higher than its commercial advantage warrants. On this account, the elements which affect these conditions should be carefully weighed.

For example, in New York City, where the standard of illumination is high and competition keen, the amount of business per square foot of floor is great and a relatively strong illumination must be provided even at a considerable cost. On the other hand, in a small town where the opposite conditions hold, the amount of light must be curtailed to keep down the expense.

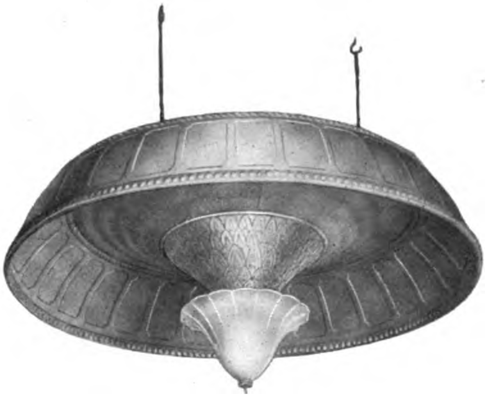


Fig. 4. Suspended Type Light Balancing Ceiling Diffuser

In both cases, however, economy is important, and it is the province of the engineer to ensure his client a lighting installation that shall best meet the conditions.

Enclosed Arc Lamps and Competitors

Owing to the development of the more refractory materials for incandescent lamp filaments, particularly tungsten, the efficiency and color of this type of lamp is being improved. These improvements, together with the practicability of increasing the candle-power capacity, are requiring a readjustment of the boundary line between the arc and incandescent lighting fields.

Unquestionably, the tungsten lamp is more suitable in some places where, previous to its development, the arc lamp would have been selected. Just where this dividing line will ultimately lie still remains to be worked out. It can not be determined until we have had further experience with the tungsten lamp. The cost of electric current will often be the determining factor.

Experience seems to indicate that high current enclosed arc lamps, fitted with proper diffusing devices, form the best equipment for the general illumination of large dry gooods and department stores.

In this connection it should be remembered that a 6½ ampere D.C. enclosed arc lamp consumes but 30 per cent. more power than a 5 ampere lamp, while it emits over 45 per cent more light. Similar comparisons for A.C. multiple enclosed arc lamps show that a 9 ampere lamp consumes 50 per cent. more power and gives over 70 per cent. more light than a 6 ampere lamp. The increased efficiency and advantages obtained with increased current seems to have been generally overlooked in efficiency comparisons. Moreover, the light from the high current arc lamp contains, if anything, slightly more yellow than average daylight. This is very desirable, as it gives a pleasing quality to the light without detracting seriously from its color selective value.

Diffusion

The demand for a more even distribution of light and the softening of contrasts and shadows resulted several years ago in the development of certain forms of diffusers. By the use of these accessories the distribution and diffusion of light was greatly improved, and although the first forms were crude and inartistic in appearance, they demonstrated the great effectiveness of diffused light. Since then new designs and improvements have been made and are still in progress. The enclosed arc lamp may be provided with a fixture suitable for use among the most beautiful surroundings, and at the same time efficiently and effectively fulfill the exacting requirements of high grade illumination.

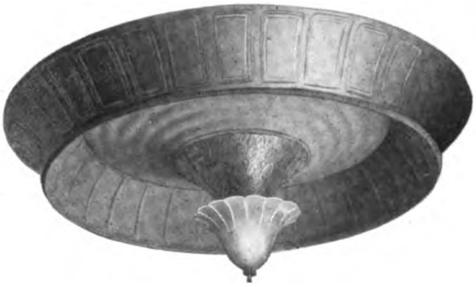


Fig. 5. Form C Light Balancing Selective Ceiling Diffuser

ELECTRIC MOTORS AND THEIR APPLICATION

By C. F. Lawrence

The subject of electric motors and their application is a very broad one, and as space is limited, I will deal with it only in a general way.

It is interesting to note that while at first the use of the electric drive was thought to be of value merely in the saving of power through the elimination of the losses due to friction in the line shafting, a higher economy has been found to lie in its remarkable effect upon the production factor of a shop.

In the average manufacturing plant, the cost of power varies from 2 to 6 per cent. of the cost of the finished product, the labor being the most important factor in manufacturing, amounting usually to upwards of one-half the total cost of the product.

The application of the electric motor to individual machines, and for driving in groups, naturally results in greater reliability of operation and increased production; as each machine or group of machines is rendered independent of all others in the shop, and yet at all times, either day or night, is fully as effective as though connected directly to the prime mover. A better control and a more constant speed is secured, and smaller shafts, lighter belts and the elimination of all heavy belting and main line shafting are obtained, these results naturally tend to a more economical operation and an increased production.

There is still a diversity of opinion as to the relative advantage of the so-called individual and group driving. The latest developments indicate a tendency towards the use of both the group and individual drive, it being generally agreed that the larger tools should he equipped with individual motors, such as machines that are intermittently driven, or where they are started and stopped to make ready or take off work. This class of machinery would include printing presses, boring mills, planers for working iron, engine lathes, certain classes of woodworking machinery, and many others.

In many shops the use of the individual drive is being extended to small tools, as well as to the large ones. It has been found that in the average machine shop at any one time during the day there is only from 30 to 40 per cent. of the tools in actual use, although all the shafting and belting is running all the time during working hours.

For small shops, the horse-power required to drive the shafting and belting alone, averages from 20 to 40 or even 50 per cent. of the engine power, and in large shops and mills from 30 to 65 per cent.

In laying out the electric drive, it is necessary to study the conditions in each individual case, as there are no two cases exactly alike.

In a printing plant where the individual drive is used, the horse-power in motors should be double the horse-power required to drive all the machines in one group by one motor. The reason for this is that it requires a little more power to start up each machine; for, with the group drive, all the balance wheel effect of all the shafting helps to start any one machine; but as it is seldom that there are more than 50 per cent. of the machines in operation at any one time, individual drive is a great saving of power. A greater advantage is gained by doing away with all belting and shafting, which always throw oil and dust, and which cut out a great deal of light. When a press is belt driven a printer has only three or four cone speeds at his command, whereas, when it is motor driven, from 8 to 15 speeds may be obtained. By having a great number of speeds, the printer is certain to secure increased production.

Before going further, I would like to speak of the advantages and disadvantages of the various types of motors, so that the proper one may be selected to run a certain class of machine.

Direct Current Motors

First, we will take up the direct current motor, the simplest type of which is the series wound machine. The series motor is used largely for driving street cars, automobiles, centrifugal pumps, cranes and hoists, being especially well adapted for electric cranes, as it will automatically regulate its speed to the weight to be raised, exerting a very powerful torque at low speed for a heavy load. The speed is regulated by either a flat or drum type controller which introduces a resistance in series with the motor, and which is usually hand controlled. When a series motor is used, it should invariably be geared or direct connected to the machine to be driven; because if a belt were used and it should slip off, the motor, being relieved of its load, would run away and might cause considerable damage.

The series wound motor is ideal when direct connected to a centrifugal pump. Assuming that the motor is large enough for the work, and that you have a certain head of water to pump against and a certain suction lift, the motor, having a certain load, will run steadily; but if the suction lift or the head should change, the load would instantly vary, causing the speed of the motor to go up or down according to load. A great many of these motors are attached to centrifugal pumps which are used to automatically fill tanks. The motor may be started or stopped by placing a ball float in the tank, this float being connected to a special quick throw switch. This arrangement will automatically start or stop the motor, depending upon the level of water in the tank.

The shunt wound motor is next to be considered. This machine will run at constant speed irrespective of load, and the torque will always be in proportion to the load.

The shunt motor may be used to run all machines where a steady, constant speed is required, such as small printing presses, ventilating fans, group driving and those machines that do not demand a heavy starting torque.

The speed of the shunt wound motor is usually regulated by means of a rheostat that inserts resistance in the armature step by step. If you have a 1 h.p. motor and wish to cut the speed down to 50 per cent. of the normal, the armature regulator not only cuts the speed in half, but also reduces the horsepower in the same proportion. The power consumed at this low speed is still 1 h.p., the other half horse-power being wasted in the resistance in the form of heat. It is not well to use this method of regulation in sizes larger than 1 or 2 h.p. This does not apply to shunt wound motors driving ventilating fans, however, because at low speed there is practically no load on the fan, but as the speed increases the power increases about in the ratio of the cube of the speed. Motors for fan work, with this means of regulation, can be used in sizes from the smallest to about 10 h.p. In larger sizes it is better to use the combined armature and field control, as it is much more economical.

The armature method of regulation is not an economical one, nor is it suitable for most machine tools, because if the speed of the motor is cut down to one-half, and the load lightens up, the speed will go up, thus giving a very unsteady drive. The speed will always be dependent upon the load, within certain wide limits.

For example, take a boring mill cutting a large circular casting, one quarter of which is cast out of reach of the boring tool. We will assume that the tool is cutting on the portion of the casting which is three-quarters of the circle, and that the motor is running at one-half speed; then, as soon as the cutting tool reaches the end of this three-quarters, the machine does no work, and the motor immediately speeds up. After the tool traverses the open quarter of the circle and strikes the casting again, the speed is so great that the tool is either likely to be broken or the casting injured.

The only proper method of speed control is to insert resistance in the field coils. With this arrangement the power remains the same throughout the entire speed range, from normal speed to maximum speed, and at any one point in this range the motor will run at practically constant speed from no load to full load.

When a machine, with a reciprocating motion which reverses and tends to lower the speed, is to be electrically driven, or when a machine is required to start with a heavy load, a compound wound motor is necessary.

In this style of motor the proportion of the shunt field ampere turns to the series field ampere turns is in the ratio of 4 to 1, this winding enabling the motor to develop a powerful starting torque. For steady speed running the compound wound motor almost equals the shunt wound machine, and can be used to great advantage for operating flat bed printing presses, planers, elevators, rock crushers, punches, shears and air compressors, and any machines which have a varying load.

In adapting motors to individual driving of machines, we have found that a shunt wound, variable speed motor may be very successfully used. This type of motor is similar to the regular shunt wound machine, except that the field coils are made extra heavy. Instead of regulating the speed by inserting resistance in the armature, as is necessary for the series wound machine, the shunt wound variable speed motor is regulated by placing resistance in the field circuit. A 5 h.p. motor, with 3 to 1 speed range, and having a normal speed of 500 r.p.m., can be increased in speed by field control to 1500 r.p.m. This represents an increase of 1000 revolutions above the normal speed, and if a controller with 20 points is used, this range of 1000 revolutions is divided into 20 steps of 50 revolutions per step. When a motor is regulated by field control, the horse-power remains the same throughout the entire range of speed, due to a proportional decrease of torque with increase of speed, and vice versa. By this method, but little power is wasted in heat, as compared with the system of armature control.

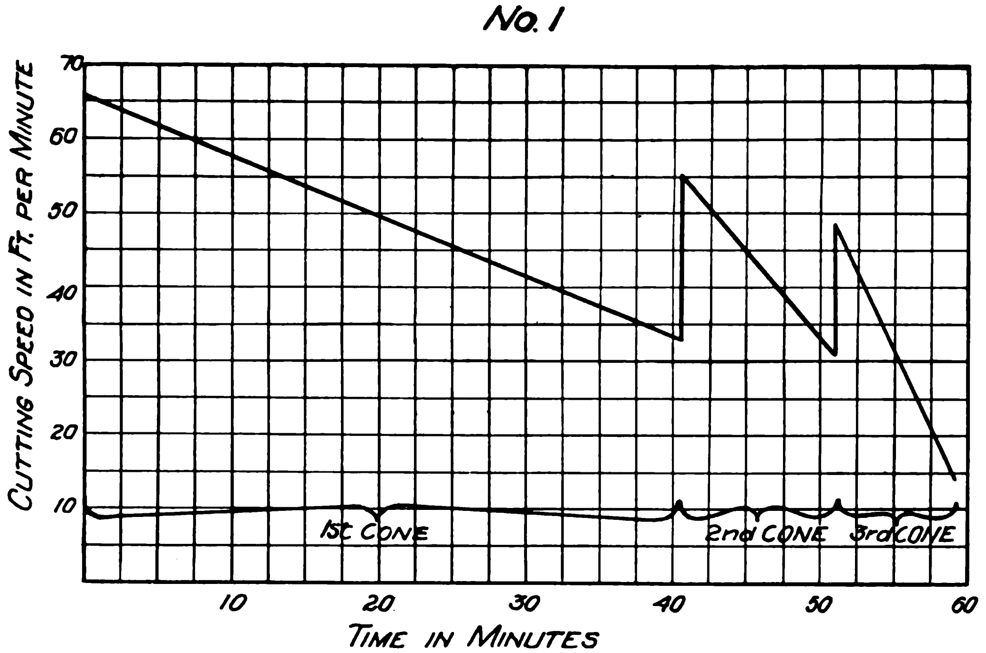


Fig. 1. Cutting Speeds and Time Required to Face a 72-inch Cast Iron Disk Using Three Steps on the Cone Pulley

The variable speed motor is ideal for engine lathes, shapers and all machines where it is necessary to run steadily on any one point of speed, from no load to full load.

The larger sizes of shunt wound variable speed motors are being built with commutating poles placed between the regulator field magnets, the object of these being to prevent all sparking on the commutator when the fields are weakened. The winding on the interpoles is in series with the armature. This type of motor is also regulated by field control, and is especially satisfactory for use on 500 volt circuits, many motor builders refusing to build ordinary field control motors for 500 volts, on account of the vicious sparking at the commutator on weak field. With the interpole motor this trouble entirely disappears. Railway motors and many types of generators are now being equipped with these commutating poles, and are very much improved by them.

Figs. 1 and 2 give a comparison between the performances of two 72 inch engine lathes of the same make, one being belt driven and the other motor driven.

Fig. 1 shows the cutting speeds and the time taken to face a 72 inch cast iron disc, from a maximum diameter of 72 inches to a minimum diameter of 6 inches, using three different steps on the cone pulley; the time for shifting the belt from one cone to the next not being included.

The cone pulleys on a mechanically driven tool do not permit the tool to start at the maximum cutting speed; and in this case, the mechanic, having no guide but his eye, did not change the speed on the cone pulley as soon as desirable for the greatest production.

Fig. 2 shows a test on a similar lathe doing the same work when driven by a motor. With the electrically driven tool, the cut begins and ends at the maximum cutting speed permitted by the work.

As will be seen from the curves, the belt driven lathe required 59 minutes to complete the cut, while the motor driven machine did the same work in 31 minutes. The electrically driven tool, therefore, accomplished the work in 53 per cent. of the time required by the belt driven lathe.

Motors can be furnished semi-enclosed or totally enclosed, and when a motor thus arranged is run intermittently or with an intermittent load, it will deliver its full horse-power without overheating; but if the motor is run continuously, it will not deliver full rated power without an excessive rise in temperature. For example, take a 2 h.p. motor running without covers. You get 2 h.p. with a temperature rise of, say, 45 degrees, and a current of 15.7 amperes on 115 volt circuit. When semi-enclosed, the horse-power for continuous operation is 1¾, with a temperature rise of 45 degrees and a current of 13.9 amperes. When totally enclosed, the horse-power is still 1¾, with a temperature rise of 60 degrees and a current of 13.9 amperes. Take another size; for instance, a 15 h.p. moderate speed motor wound for 115 volts; when running open the motor develops 15 h.p. with a temperature rise of 45 degrees and a current of 111 amperes. When this motor is semi-enclosed for the same temperature rise the horse-power is 10, with a current of 74.5 amperes. When totally enclosed, with a temperature rise of 60 degrees, the horse-power is only 7, and the current 52.8 amperes.

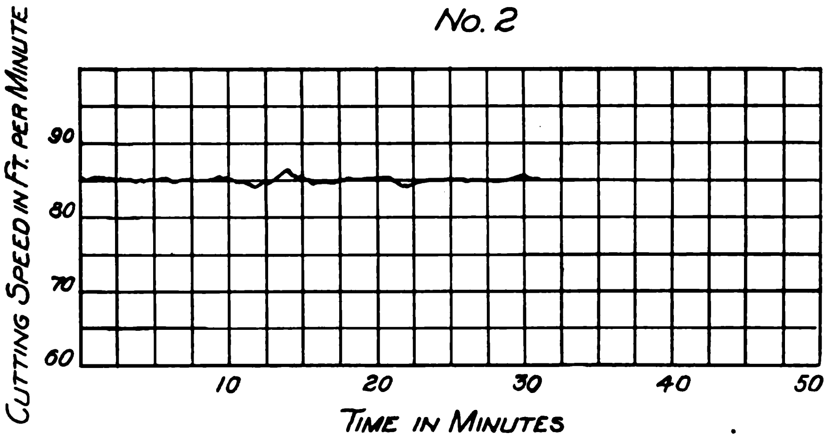


Fig. 2. Cutting Speeds and Time Required to Face a 72-inch Cast Iron Disk With Lathe Driven by Motor with Field Control

Induction Motors

The wide field of application of the polyphase induction motor is due to the many advantages inherent in its design. It is extremely simple and may therefore be built to withstand hard usage, and may be run continuously in exposed locations and under unfavorable conditions. The absence of a commutator contributes much towards this reliability, and at the same time reduces the items of maintenance and repairs. The efficiency obtained in this motor over wide load ranges, and the small amount of attention it requires while running, make it compare favorably in cost of operation with motors of any other type. Other advantages may be briefly summarized as follows:— Ability to carry large overloads for considerable periods without serious overheating; entire absence of sparking, permitting it to be used in powder mills, gas houses and other places where direct current motors would be dangerous; quick and certain starting under full torque, and simplicity of starting gear.

In order to choose the proper motor to be used for a certain purpose, it is necessary to look into the advantages and disadvantages of the various types of induction motors.

First, we will take up the single-phase motor. The field for the use of these motors of moderate capacity is constantly growing by reason of the increasing tendency of central stations to generate polyphase current and feed a large portion of the lighting load through single-phase distribution. Power is frequently required near such circuits for the operation of light machinery.

The motor is rendered self-starting by means of a starting box containing resistance and reactance, and a double-throw switch for the 1 h.p. motors and larger. The switch is first thrown to the starting position, and when the rotor has attained almost full speed is quickly thrown over to the running position, the object being to first connect the resistance and reactance in circuit with the motor and then to disconnect it.

The starting box furnished with the ¼ h.p. and ½ h.p. motors has a single-throw spring release switch. To start these motors, the operator holds the switch blades down on the lower contacts until the rotor has reached almost full speed, then upon releasing the switch handle, the blades spring up into the running position.

Next come the two and three phase induction motors; the latter being now the standard alternating current motor. The two and three phase machines are made in forms *K*, *L*, and *M*.

The form *K* motor has a low resistance squirrel-cage armature, and is started by means of an oil-immersed starting compensator. This motor can be used in dusty places, gas houses, powder mills, or where it is to be controlled from a distance. The use of this type of motor is limited in some places, on account of heavy starting current.

The form *L* motor has the same field windings as the form *K*, but the armature is wire wound, and has a starting resistance attached to the armature spider, which is cut in and out of circuit with the armature windings by means of a connecting rod or lever. This form of motor is used more than any other on account of the low starting current required. The operation of the *K* and *L* motors is the same when up to speed.

The form *M* motor is designed for variable speed service, such as cranes, hoists, dredges, etc. Speed changes are obtained by means of an external adjustable resistance in the rotor or armature circuit. This resistance is usually made up in the cast iron grid form, and is connected with a drum type controller having 8 or 14 points for speed control.

The terminals of the armature winding are brought out to collector rings mounted on the shaft and fitted with brushes, to which the wiring from the controller and resistance is connected.

Suitable resistance can be furnished for:

First. Starting duty only.

Second. Starting resistance only from zero to half speed, and from half to full speed. The resistance is made heavy for continuous operation on any one point, when used with motors hoisting with a long lift.

Third. For continuous duty on any point from zero to full speed. This is used when operating calender rolls for any length of time on any one speed.

The form *M* motor for constant speed continuous running is made from the same frame as the form *L*, and the armature fitted with collector rings. This same motor, when used intermittently for crane or hoist duty, can be rated 50 per cent. higher than the continuous duty motor.

The form *M* motor is especially suited for running hydraulic elevators, an outfit for this work consisting of a form *M* motor geared to a triplex pump, a drum type controller and set of starting resistances. The controller is fitted with a pinion and rack which is connected to a Mason water regulator, and this in turn is connected to the water service pipe in the building. The Mason regulator has a diaphragm which is set for a given water pressure in the receiver tank connected to the plunger elevator. When this pressure falls 5 lbs., the diaphragm opens the valve to the regulator, and its piston slowly turns the controller of the motor until the motor is up to speed. The motor continues to run the pump until the pressure has reached its normal point in the receiver tank; the regulator then shuts off the current to the motor and the pump stops, and remains at rest until the pressure in the receiver tank falls again. A number of these outfits are in daily use under severe conditions, and to my knowledge have never given one minute of trouble.

As a general summing up, the advantages of the electric drive are:—Saving of power; greater flexibility; better light and ventilation, since there is no obstruction by shafting and belting; absence of dirt and grease thrown about by shafting and belting; reduced fire risk; reduced cost of repairs; and entire absence of power loss when machines are not in operation.

INFLUENCE OF WAVE FORM OF E. M. F. ON CORE LOSS AND EXCITING CURRENT IN TRANSFORMERS

By L. T. Robinson and O. Holz

General Electric Standardizing Laboratory

One of the most important tests in connection with the manufacture and use of transformers is the determination of their core loss. This loss varies through quite wide limits when the determinations are made using waves of impressed electromotive force having different shapes.

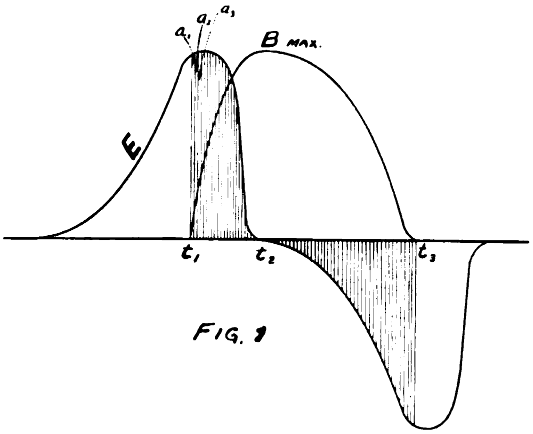


FIG. 1

On account of the existing difference between the core loss for various e.m.f. waves it is desirable to state all such losses in terms that allow of their direct comparison. For various reasons the sine wave is most desirable for general use and most modern generators are constructed to produce such a wave; therefore, any core loss should be stated in terms of the loss occurring on a sine wave, and any losses determined on other than sine waves should be corrected to that standard. The exciting current is also of interest and the effect of wave form variations on this quantity is also something which should be corrected for and the results reduced to the same standard basis.

The core loss consists of two components, that due to hysteresis, and that due to the eddy currents in the iron sheets.

The effect of wave form variations on these two components will be considered separately and in the order given.

The fact is well known that the hysteresis loss is proportional very approximately to the 1.6 power of the maximum magnetic density. It is, therefore, necessary to find the relation between the wave shape of e.m.f. and this maximum.

Neglecting the small $I\,R$ drop of the exciting current which is also out of phase with the impressed e.m.f., we have:

$$e = K \frac{d\,B}{d\,t} \tag{1}$$

where e is the instantaneous value of the e.m.f. impressed and B is the corresponding density within the transformer iron. K is a constant, depending on the cross section of core, the turns of winding surrounding the same and the conventional relation between e and B.

$$\therefore e\,d\,t = K\,d\,B \tag{2}$$

$$\text{and} \int_{t_1}^{t_2} e\,d\,t = K\int_{B_{\text{zero}}}^{B_{\text{max}}} d\,B \tag{3}$$

$$\text{or } e \text{ average } (t_2 - t_1) = K\,B_{\text{max.}} \tag{4}$$

where t_1 is the time at the beginning of integrating and t_2 that at the end, $t_2 - t_1$ representing the time taken for the flux wave to pass from 0 to maximum value. Equation 4 expresses the fact that the maximum density is proportional to the area of the e.m.f. curve between t_1 and t_2.

The flux curve is at its maximum point when the electromotive force curve $\left(\frac{d\,B}{d\,t}\right)$ is zero; or conversely, the flux has reached its maximum when $e = 0$.

In an alternating current circuit as much flux enters as leaves the core; it follows that the positive area, expressed by $e\,(t_2 - t_1)$ of the e.m.f. wave must equal the negative area of the e.m.f. wave between t_2 and t_3, where t_3 is the point of maximum negative e.m.f.; that is, the area to the left of the maximum B ordinate must equal that to the right of the maximum; hence the area of the e.m.f. wave from t_1 to t_3 is proportional to the maximum flux B. Half the area of the e.m.f. wave determining the rise and the other half the descent of the flux wave.

It is sometimes desirable to draw the wave of flux from the wave of e.m.f. Bisect the area of the e.m.f. wave and plot B ordinates proportional to the small areas a_1, $a_1 + a_2$, $a_1 + a_2 + a_3$, etc., as shown in Fig. 1. The sum of all the small areas so shown is, $e\ (t_1 - t_2)$ and the sum of all the small flux increments corresponding to the areas a_1, a_2, a_3, etc. is the total or maximum flux or density B. Thus again ½ the area of the e.m.f. wave is proportional to the maximum B and consequently the whole area is proportional to this quantity also.

The area of any wave equals the average ordinate times the abscissa, and for different waves having the same abscissa or time, the areas and maximum fluxes are proportional to the average e.m.f.

To compare two e.m.f's. of different wave shape they must first be reduced to the same a.c. voltmeter reading, or effective value; consequently the core loss, due to an e.m.f., a, is to the core loss due to an e.m.f., b, as

$$\left(\frac{\text{average e.m.f. of } a}{\text{effective e.m.f. of } a}\right)^{1.6}$$

is to

$$\left(\frac{\text{average e.m.f. of } b}{\text{effective e.m.f. of } b}\right)^{1.6}$$

The ratio of the effective e.m.f. to the average e.m.f. is called the form factor of the wave. That is, the core loss due to a, which we want to compute from the core loss due to b (which latter we have found by test), equals:

$$\text{core loss of } b \times \left(\frac{\text{form factor } b}{\text{form factor } a}\right)^{1.6}$$

That is, the greater the form factor, the smaller the core loss.

The form factor for a sine wave is 1.11, for a rectangular wave 1.00, and for a pointed wave it can reach almost any assignable value; theoretically, the limiting value is infinity.

The flux wave may also be recorded directly by moving two brushes, separated by an angle corresponding to half a cycle, around a synchronously driven commutator to which is connected the e.m.f. to be investigated. The readings on a direct current voltmeter connected to the brushes are proportional to the instantaneous flux in the transformer core; and these readings, obtained step by step, and plotted or recorded continuously, will give the B curve.

The flux wave can also be found by means of the oscillograph and a reactance without iron (the resistance of which is negligible as compared with its inductance), by taking an oscillogram of the current flowing through it when connected to the e.m.f. wave whose corresponding flux wave is desired. In this case the current wave is identical in form with the flux wave that would be produced in a transformer core, varying permeability and hysteresis not entering as disturbing elements.

The eddy current loss is equal to $\frac{E^2}{R}$

where E is the effective electromotive force induced in the sheet iron punchings, and which is of the same wave shape as the impressed e.m.f. R is the resistance of the laminæ to the eddy current. This eddy loss is not effected by wave shape unless self inductance is present, which cannot be as its presence would change the flux. This cannot occur as the flux is determined by the impressed e.m.f. This eddy loss is an $I^2 R$ loss, and is therefore proportional to the effective value of the eddy current, and is not influenced by its wave shape. The eddy currents could be kept near the surface of the individual sheets due to skin effects, but as the laminæ are thin, this effect cannot produce appreciable variations in the loss at commercial frequencies; especially as the skin effect varies only as the square root of the frequency. Supposing a transformer has an eddy current loss (as found by a separation test of losses made at different frequencies at the same e.m.f.), amounting to 20% of its total loss. Suppose it has an 80% hysteresis loss and that we have found the form factor of the wave to be 1.25. We want to know what will be the core loss with the transformer connected to a sine wave.

We have

$$W = .20 + .80\left(\frac{1.25}{1.11}\right)^{1.6} = 1.23$$

that is, the loss will be 23% higher than that found in the test.

The effect of wave form on the exciting current will be considered next.

(To be continued)

THE TANTALUM LAMP
THE SALVATION OF OVERLOADED SYSTEMS

By Oliver F. Brastow

The late President McKinley once remarked that the word "cheap" was not attractive to him, and in the same sense, the mere word "expensive" is meaningless. The first cost of an article cannot be considered high or low until its real value has been determined, not only from a utilitarian, but from an investment standpoint. This statement suitably sets forth the commercial position of both tungsten and tantalum lamps.

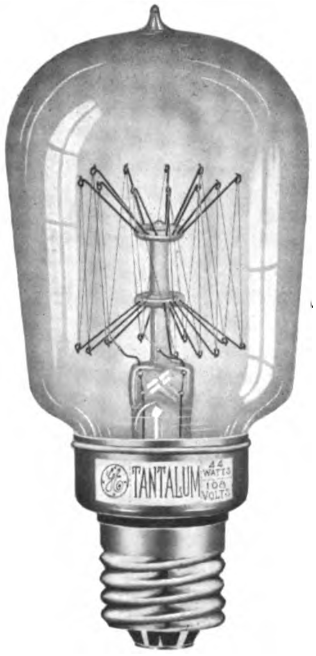


Fig. 1. Tantalum Lamp

The latter will be considered in some detail for the reason that this form of high efficiency lamp, at the present time at least, seems to be the most popular by reason of its availability in small units. This is, however, but a temporary consideration, because the tungsten already shows promising characteristics, and furthermore, the mechanical features of the tantalum lamp are essentially difficult to perfect. Many thousand tantalum lamps have been sold during the past few months; and it is gratifying to know that this type of lamp, now being produced on a large scale in the United States, shows a very marked improvement over the imported article that was first offered for sale in this country.

While exploiting the sale of the tantalum lamp in New England, the writer found some very interesting cases where the lamp in question served its purpose so acceptably well that its use was relatively not expensive.

In presenting the merits of tantalum lamps to prospective customers operating isolated plants, the first question which may profitably be asked by the salesman is, "Have you sufficient capacity?" If a negative reply is given, then the prospective customer can certainly be interested in the lamp. The writer has disposed of many thousand tantalum lamps to customers whose generators were previously overloaded, and in every instance the most satisfactory part of the transaction was that the customer was greatly benefited by his purchase, and realized the fact.

A concrete example will serve to illustrate the most practical application of the tantalum lamp. The superintendent of a certain small industrial plant was approached with the regulation preliminary question on the subject of his lighting, and it was found that a thousand 16 c.p., carbon filament lamps constituted a heavy and excessively dangerous overload on both his engine and generator. An indicating wattmeter showed that the lamps installed were taking 65 watts each, while the 20 c.p. tantalum lamp, of course, showed 40 watts. The proprietor was not slow to appreciate the difference that the new lamp would make, and an order for one thousand was secured. He had previously insisted on buying a very ordinary incandescent lamp because of its "cheap" price; its only cheap feature, however, being its first cost, as was sadly acknowledged later. Let us consider what the change from the cheap variety to the tantalum lamp was really worth in this instance.

A gain in capacity of 25 kw. was secured, and at an estimated cost of $100 per kw. (which is a fair valuation in this case, for engine, boiler, generator capacity, etc.), this amounts to $2500.00.

Interest on the above at 5 per cent.	$125.00
Depreciation at 6 per cent. . . .	150.00
Taxes and insurance	25.00
Cost of operating 2500 kw. for 800 hours (the life of the lamp) at 2 cents per kw. hr.	400.00
	$700.00
Difference in *cost* of 1000 tantalum lamps and the cheap lamps formerly used	340.00
Saving	$360.00

This saving does not take into account the time and trouble necessary to make the change, although as an offset to this expense the remarkably enlarged capacity obtained from the existing plant with identically the same main or initial installation must be considered. Many other cases of a similar nature could be mentioned, but the one described is typical of many existing instances and clearly illustrates the value of high efficiency lamps in small units when used under proper conditions.

Another important consideration in connection with the tantalum lamp is the advantage to be gained by the use of any highly economical lamp when operating on a meter basis. This is made evident by a very simple calculation, which can be easily performed by the average laymen.

The tantalum lamp is but a forerunnner of better things to come, and the day is not far distant when the most humble cottage will be electrically lighted, and kerosene will have a most worthy and overwhelming competitor in a lamp giving light at about 1 watt per candle-power. At such a time the central station will enjoy a tremendous increase of patronage; it will be recognized as the only logical purveyor of power for illuminating purposes, and the general adoption of domestic heating units will be remarkable. Small isolated plants will disappear, and the new lamp will mark a definite advance in the achievements of civilization.

Light has been employed as an emblem of welfare, prosperity and happiness since the beginning of the world, and the producer of an inexpensive and satisfactory means of providing the small customer with good light will be numbered among the world's benefactors.

POLYPHASE MAXIMUM WATT DEMAND INDICATOR, TYPE "W"

By W. F. Howe

Commercial maximum demand indicators have hitherto been confined to devices which would indicate the maximum ampere demand only, and which were obviously not suitable for recording the maximum load on alternating current circuits of other than unity power factor and constant voltage. In many cases, particularly in motor installations, it is necessary to know the actual maximum watt consumption, and for this reason the General Electric Company has designed a Polyphase Maximum Watt Demand Indicator, two views of which are shown in Figs. 1 and 2.

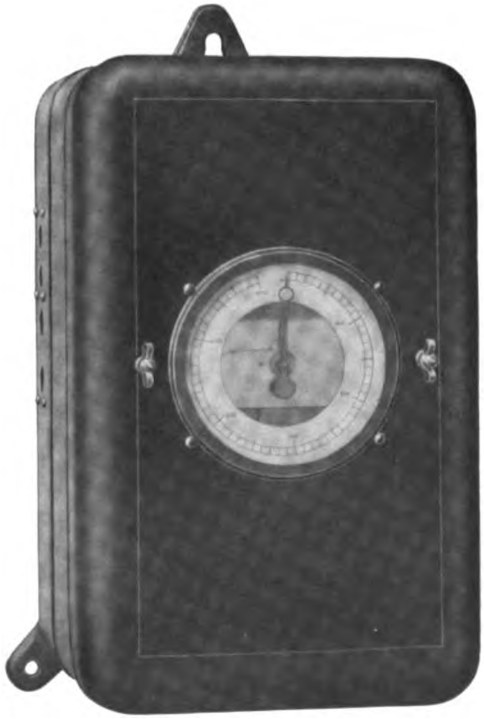


Fig. 1. Polyphase Maximum Watt Demand Indicator

This instrument will indicate correctly, within commercial limits, on two or three phase circuits, with balanced or unbalanced, inductive or non-inductive loads. It may also be used on single phase circuits by making the proper connections.

The device is, in its essential elements, a type "D-3" polyphase wattmeter with both electrical elements acting on the top disk, together with a very strong damping system acting upon the lower disk to provide the necessary time lag. In place of the usual register, there is provided a single graduated dial and two pointers, one of the latter being driven through a train of gears by the moving element of the indicator and indicates the energy passing through the device at any moment, subject to a correction due to the time lag. The second pointer is driven by the first, and is left at the maximum position reached by the latter, being held in place by a ratchet. This second pointer indicates, then, the maximum energy which has passed through the device since it was last set. The maximum demand pointer is re-set to the zero position by a thumb nut which may be sealed to prevent meddling by unauthorized persons. As this device is for the purpose of indicating, and not recording the amount of energy passing through it, the motion of the rotating element is opposed and controlled by phosphor-bronze springs.

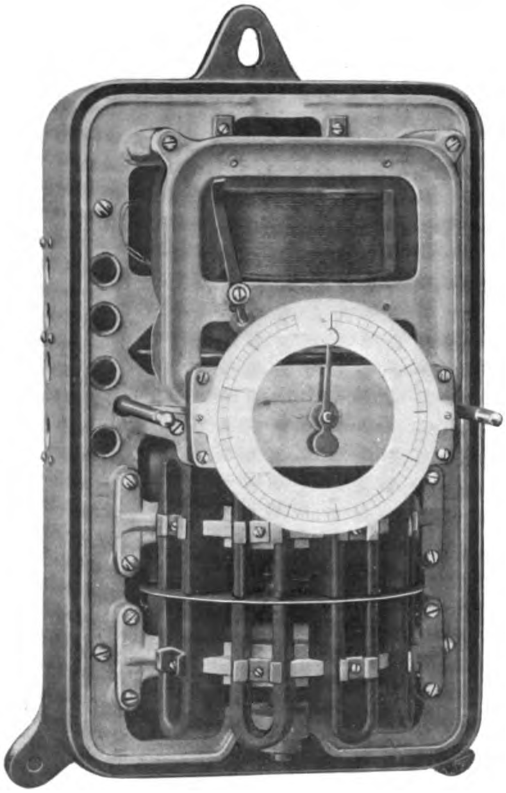


Fig. 2. Maximum Demand Indicator. Cover Removed

The torque is proportional to the energy flowing through the device, and this, in connection with the spring control, gives a uniformly divided scale.

The degree of time lag, or in other words, the length of time required for the pointer to reach its maximum position, will depend upon the torque of the motor elements and the strength of the damping magnets. By changing these variables, the Polyphase Maximum Demand Indicator may be arranged for a time lag, ranging from one minute to thirty minutes. An indicator having a definitely rated time lag may, by an adjustment of the damping magnets, be given another time lag differing from the original by from ten to fifteen per cent. These indicators are rated by defining the time lag as 90 per cent. of full scale, for the reason that between 90 per cent. and 100 per cent., the movement of the pointer is very slow compared to the speed from zero to 90 per cent. The character of the pointer movement is shown in Fig. 3.

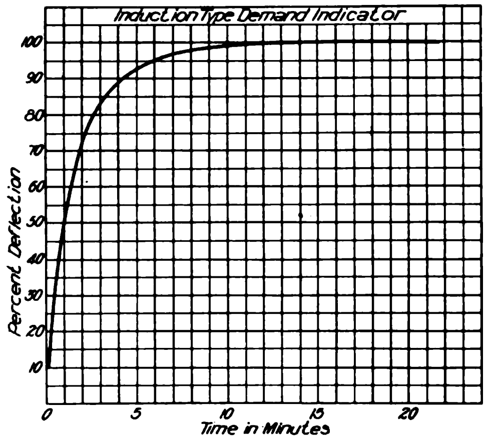


Fig. 3

The Polyphase Demand Indicators, in sizes above 25 horse-power capacity, are made with the same ratings as polyphase meter, for both secondary and primary circuits. Dimensions, connections and finish are practically the same as the "D-3" polyphase meter.

THREE-PHASE TO TWO-PHASE TRANSFORMATION WITH SPECIAL REFERENCE TO CORE TYPE TRANSFORMERS

By W. J. Wooldridge

Attempts have at times been made to operate regular single-phase core-type transformers on three-phase primary two-phase secondary circuits, and as these attempts are often not successful it seems advisable to point out as briefly as possible the reasons for such failures, with the hope that a clearer understanding of the conditions in the windings may prevent the trouble, sure to result from wrong practice in this particular.

In the transformation of power by means of the T connection there arise certain peculiar current and voltage relations which at first sight are liable to escape ordinary observation, but if disregarded are sure to result in serious unbalancing. The relation between the currents on the two sides of the primary winding of the main transformer make it absolutely necessary, if this distortion is to be avoided, to "balance" each half of the winding on the legs.

In the accompanying figure, a, b, A, are the primary and secondary of the main transformer in the T connection, and c, C, corresponding coils of the teazer transformer. Considering current I_s amperes drawn from the secondary A of the main transformer, an equivalent current must then flow through the primary a, b. With current I_s taken from the secondary C of the teazer transformer, the equivalent primary current must be

$$\frac{2}{\sqrt{3}} I_s$$

which is 90 degrees out of phase with the current in the main transformer. This teazer current divides into two parts; one half,

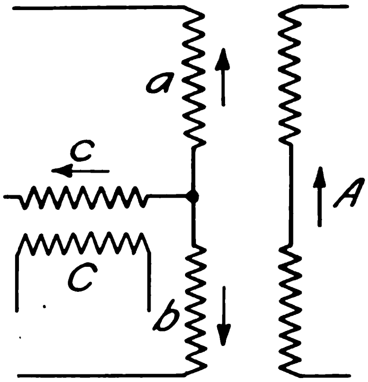
$$\frac{I}{\sqrt{3}}$$

flowing in main b, and the other half in main a. Since this current flows in opposite directions in the two halves, and, as above stated, is 90 degrees out of phase with the main current, it lags 90 degrees behind the main current in one coil and leads by 90 degrees in the other.

These extra currents have no equivalent secondary current in the main coil, since they are equal and flow in opposite directions in a and b, and therefore neutralize each other as far as magnetizing effect is concerned.

Hence the coils a and b may be considered, with relation to the teazer current which flows in them, as a single-phase transformer, one coil being the primary and the other coil the secondary.

In any core-type single-phase transformer, the secondary is never wound all on one leg and the primary all on the other leg, because such an arrangement would introduce a large leakage flux, the effect of which is to increase the reactance of the transformer. The primary and secondary coils are always placed as near together as good insulation permits in order to reduce to a minimum the flux which does not link both coils.



If these same precautions are not taken in connection with the main coil of the T transformer, a large reactance drop will result. This reactance drop is 90 degrees ahead of the teazer current, and since the teazer current in the main coils lags 90 degrees behind the main current in one core, and is 90 degrees ahead of the main current in the other core, with a non-inductive load the reactance drop in one coil is in phase with the electromotive force across the coil, and opposite in phase to the electromotive force across the other coil. Therefore the reactance drop increases the voltage across one side and decreases it across the other side of the main coil.

The necessity of reducing the reactance between the two sides, by balancing each side of the main coil on each leg, to prevent this distortion, is easily understood with the above facts in mind.

ELECTRICALLY EQUIPPED HOSPITAL LAUNDRIES

By W. H. Rue

The Philadelphia Hospital Laundry affords a good example of the readiness with which electricity may be adapted to laundry work. The building in which this laundry work is done is a one-story substantial stone structure, having 10,500 feet of floor space divided into one large room and a boiler room. It is well lighted during the day by windows and a skylight extending the full length of the building, and by arc lamps at night. The boiler room contains one 95 h.p. and one 125 h.p. water tube boilers, which supply steam at both high and low pressures for the general laundry work. There is also in this room a 50 h.p. motor, belted to a shafting which extends the full length of the building.

The large room contains the washing machines, centrifugals, conveyors, hurricanes, mangles, etc., which are directly belted to the line shafting; the end of the room is used for the hand-ironing department. It was originally arranged for stove-heated irons, and little or no thought was given to modern construction, representing convenience and efficiency. One of the serious problems which the management had to face in contemplating a change in the methods then employed, was the fact that the inmates of the Institution did all the hand-ironing, and that whatever system was finally adopted, should be fool-proof, to avoid damage by overheated and soiled irons, as many of the inmates were feeble minded. The electric iron solved the problem.

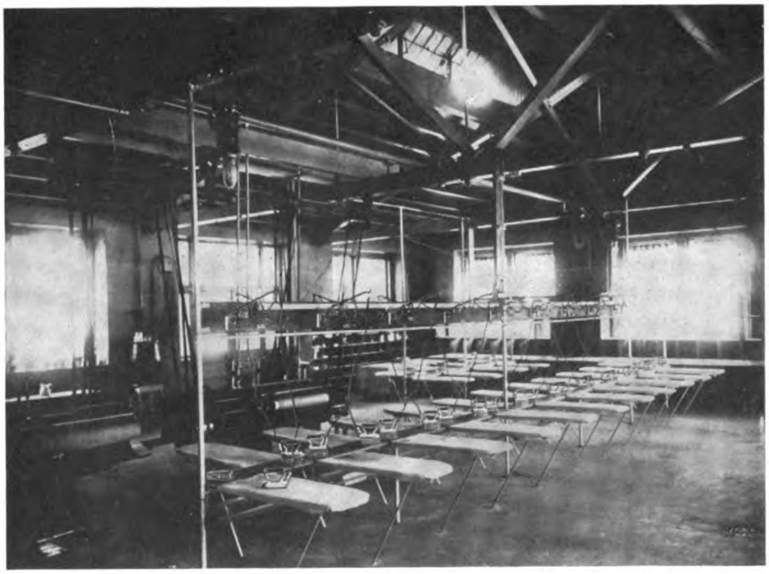


Fig. 1. Electrical Laundry, Showing Boards in Position for Work

Mr. Search, manager of the laundry, devised a special arrangement of ironing-boards, which is unusually compact and convenient. Two horizontal pipes 1½ in. in diameter, located three feet and seven feet from the floor, respectively, are supported by three vertical pipes extending from the floor to the ceiling. Above the second pipe is fastened a 1 in. by 6 in. board, on which are mounted, over each ironing board, a keyless receptacle and a single-pole knife switch. At right angles to the board, a horizontal arm 2½ feet long is secured, and to the end of this arm is fastened a spring for keeping the attaching cord taut when the iron is in use. Below the lower horizontal pipe, and parallel to it, is a semi-circular wire basket, used as a catchall.

The broad end of the ironing-board is hinged to the lower horizontal pipe, while the small end is supported by a movable arm, which, when in use, fits into a floor socket, Fig. 1 shows the position of the board when in service.

When not in use, the boards are raised to a vertical position, and are clamped to the switchboard, which is mounted on the upper horizontal pipe. Fig. 2 shows the position of the boards when not in service.

On the broad end of each board is bolted a special three-deck stand, having side clamps for holding the iron when the board is not in use and in a vertical position. The iron used is the standard 6-pound, 110 volt cartridge unit type, built by the General Electric Company. There are 48 of these irons installed, and an average of 97,000 pieces are ironed here each month, with the inmates working eight hours per day. With the same number of irons, it has been found that from 20 to 30 per cent. more work is done now, than formerly, with the additional advantage of securing better work, and easier labor for the workers.

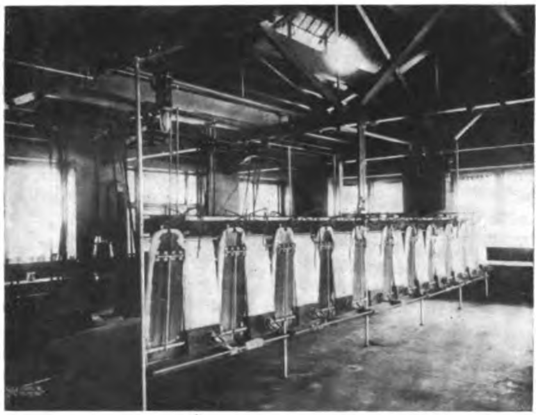


Fig. 2. Showing Position of Boards when not in Service

While the equipment of this laundry demonstrates the three distinct uses of electricity; namely, for purposes of light, power and heat, it shows particularly the value of electricity for *heat.*

NOTES

PERFORMANCE OF A SMALL TURBINE

The following letter, recently written by the Manager of the Lighting Department of the General Electric Company's Chicago office, to one of the Company's engineers at Lynn, gives an instance of the splendid service afforded by Curtis turbines, often under very adverse conditions:

"The engineer in charge of the train lighting equipments for the C. B. & Q. Railroad was in to-day and told me that only a few days ago they operated one of our 25 kw., 125 volt non-condensing Curtis turbines at 45 lbs. steam pressure, and were able to carry 180 amperes at 110 volts. This was such a remarkable showing that I was much inclined to question the accuracy of his figures, but he insists most positively they are right.

"He tells me that when the Chicago City train pulls out of Kansas City, the turbine is located in the rear end of the third car back of the locomotive, and that they never get over 60 lbs. pressure until after one or both of the mail cars ahead of the turbine car are cut out, but that notwithstanding this they are able to carry their load."

* * * *

PITTSFIELD SECTION A.I.E.E.

The Pittsfield Section of the A.I.E.E. held its seventh meeting of the season at Hotel Wendell on February 6th. Ninety members were present and heard a very interesting talk by Mr. E. J. Berg upon the "Phenomena Occurring on High Voltage Power Transmission Lines."

Mr. Berg accompained his remarks with a number of diagrams and formulæ and gave actual figures obtained by tests made under operating conditions. The subject was handled in a clear and effective manner.

A brief discussion followed the address in which interesting comments were made by Mr. C. C. Chesney, Mr. W. S. Moody, and others.

At the meeting of the Section held on January 4th, a new departure was tried and an informal smoker was held. Answers were given to a number of questions covering a wide range of subjects, which had been handed in previous to the meeting, the chairman calling on various members present for replies. As an experiment the results were satisfactory and it is probable that similar meetings will be held in the future.

The meeting scheduled for February 21st was postponed, due to a conflict of dates with the annual banquet of the University Club of Berkshire County, many members of the Pittsfield Section being interested in the latter affair.

* * * *

In the article on "Illumination of Niagara Falls" in the February issue of the "GENERAL ELECTRIC REVIEW," we inadvertently omitted to explain the excellent view on page 119 and failed to give proper credit for it. The view is a photographic representation of the effect of night illumination of Niagara Falls, for which credit should be given to Mr. Geo. E. Curtis, the well-known Niagara Falls photographer.

BOOK REVIEWS

EXPERIMENTAL ELECTRICAL ENGINEERING

By V. Karapetoff

John Wiley & Sons. 790 Pages. Price $6.00

Up to within the past two or three years, there was a relative dearth of electrical books that dealt with the science of electrical engineering as a whole, and a student must needs have purchased a small library if he desired to familiarize himself with the different branches of the subject. One book would treat of generators and perhaps motors, another of railways, and yet others of lighting, power transmission, etc. Recently, however, several authors have written general treatises, "Experimental Electrical Engineering" by V. Karapetoff being the latest book of this description. This work is essentially a text book to be used under the guidance of a teacher and with his supplemental instruction, as a number of formulæ and mathematical expressions are given and the method of their deduction omitted. For this reason the book does not seem to be especially well adapted for self instruction.

The author advocates the so-called "concentric method of teaching" and the book is so arranged as to be used in this manner if desired. By the concentric method the student is first "introduced to the whole scope of his profession, though in a very elementary and popular manner," in order that he may secure a general view of the subject. Later, he covers the same subject a second, third or more times, the repeated courses increasing in difficulty as he advances.

In addition to its use in the college laboratory the book is of value as a reference work for engineers.

ELECTRICAL ENERGY, ITS GENERATION, TRANSMISSION AND UTILIZATION

By Ernst Julius Berg

McGraw Publishing Co. [198 Pages. Price $2.50

This book, which owes its origin to a course of lectures given during the last few years by Mr. Berg at Union University, is one of the most important and valuable additions to the literature of electrical engineering that has appeared during recent years. It deals with the application of the science of electrical engineering to the practical design and operation of modern electrical plants, covering the field in a manner that is thorough and at the same time very easily understood. That is, while mathematics is used when required, mathematical formulism is avoided wherever the problems and their solution can be made clear without it, and the book will therefore be very useful to those engineers who do not care for extensive mathematical investigations.

The most important and valuable feature of the book is the broad and general point of view from which the subject is treated. It is not written by a specialist in one branch of electrical engineering, who in dealing with general problems would necessarily look at them from the point of view of his special branch; but by a man who for fifteen years has had a wide experience in all branches of the art, and who is therefore qualified to weigh and discuss in an impartial manner the relative advantages and disadvantages of the different methods, systems and apparatus entering into the modern electrical system, in their relation to design, construction, and operation.

As our readers know, Mr. Berg has been for many years in the closest possible touch with the design of all electrical apparatus and systems as well as the investigation and development work of the General Electric Company. He has thus acquired a broad and comprehensive experience in the subject dealt with in his book.

The present volume deals in the first section with the transmission line, discussing the principles of design and calculation as affected by the practical requirements of operation under normal and abnormal conditions. In the second section the generating system is taken up and discussed in the same broad and thorough manner, not only from the electrical side, but also in regard to the question of prime movers, such as reciprocating engines, steam turbines, gas engines, etc.

As the book is easily read and well worth reading, an extensive review of the contents is hardly necessary. It is to be hoped that Mr. Berg will soon be able to follow this volume with a second one dealing with the receiving station and the uses of electrical power.

C. P. STEINMETZ.

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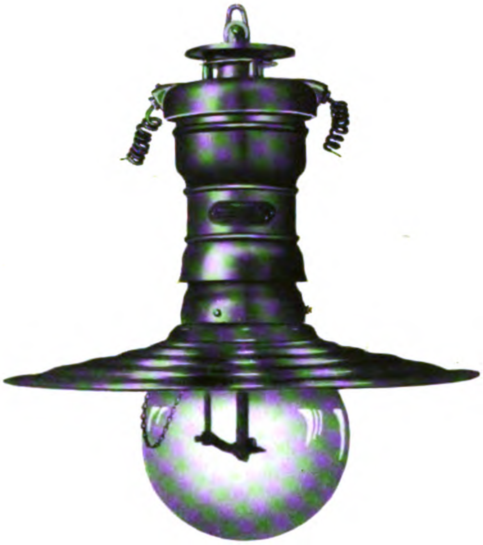

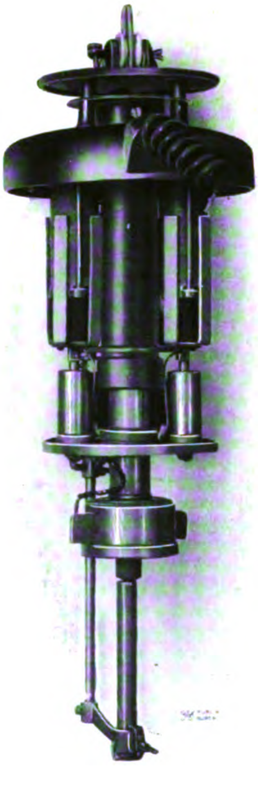

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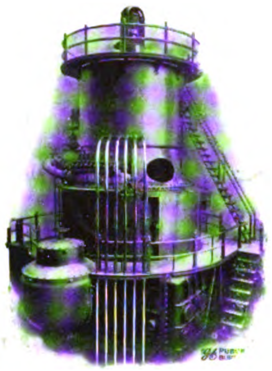
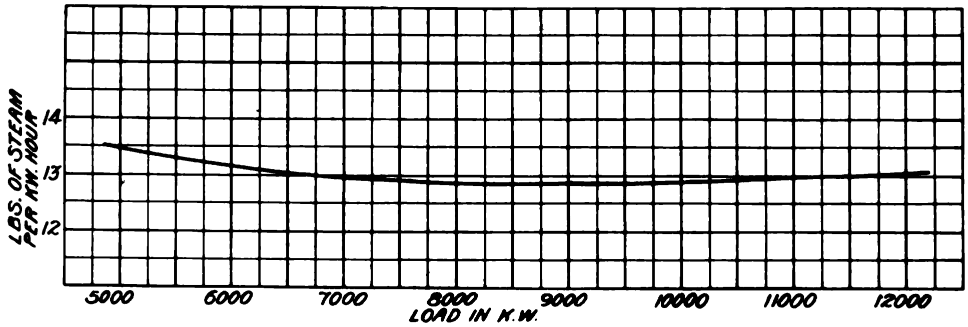


Curtis Steam Turbines show a nearly constant efficiency over a wide range of load

The following load curve is based on tests made in the Fisk Street power house of the Commonwealth-Edison Company, Chicago, Ill., and shows a maximum variation in economy of 5 per cent from 5000 to 12000 kilowatts



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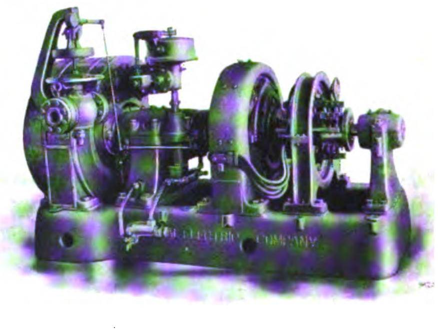

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GENERAL ELECTRIC REVIEW

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VOL. X, No. 6

PUBLISHED MONTHLY BY
GENERAL ELECTRIC COMPANY'S PUBLICATION BUREAU
SCHENECTADY, NEW YORK

MAY, 1908

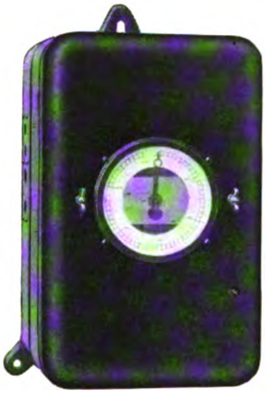
100 WATT TUNGSTEN LAMP

(See page 285)

A New Instrument

The General Electric Company's

Maximum Watt Demand Indicator



This is the *first and only* maximum demand instrument that indicates true watts regardless of power factor or voltage fluctuations on any commercial alternating current circuit.

The actual maximum demand for energy is indicated after the rated time duration which ranges from one to thirty minutes in different instruments. Any rated time may be varied ten to fifteen per cent. by simple adjustments.

This indicator is invaluable for obtaining peak load conditions

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VOL. X, No. 6 MAY, 1908

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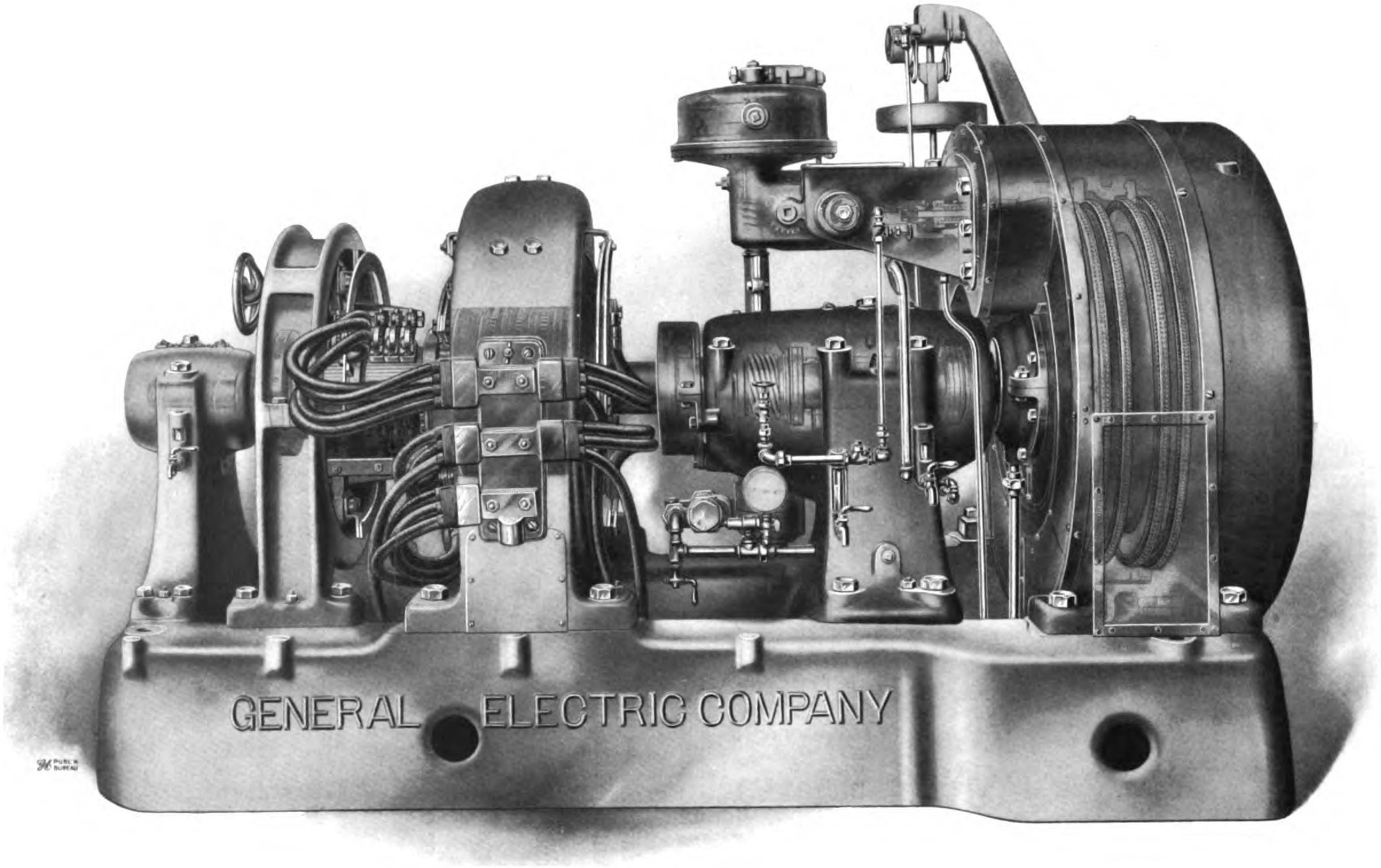

Phantom View of Curtis Steam Turbine Direct Connected to 100 Kw. Direct Current Generator
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GENERAL ELECTRIC REVIEW

STANDARD RAILWAY CONVERTER SUBSTATIONS

By J. E. WOODBRIDGE

Railway Converter Substations

The requirements of direct current railroad substations are so similar in the majority of cases that it is possible to adhere to a general equipment which will be approximately uniform and at the same time incorporate all those factors which provide for safety, convenience of operation and economy.

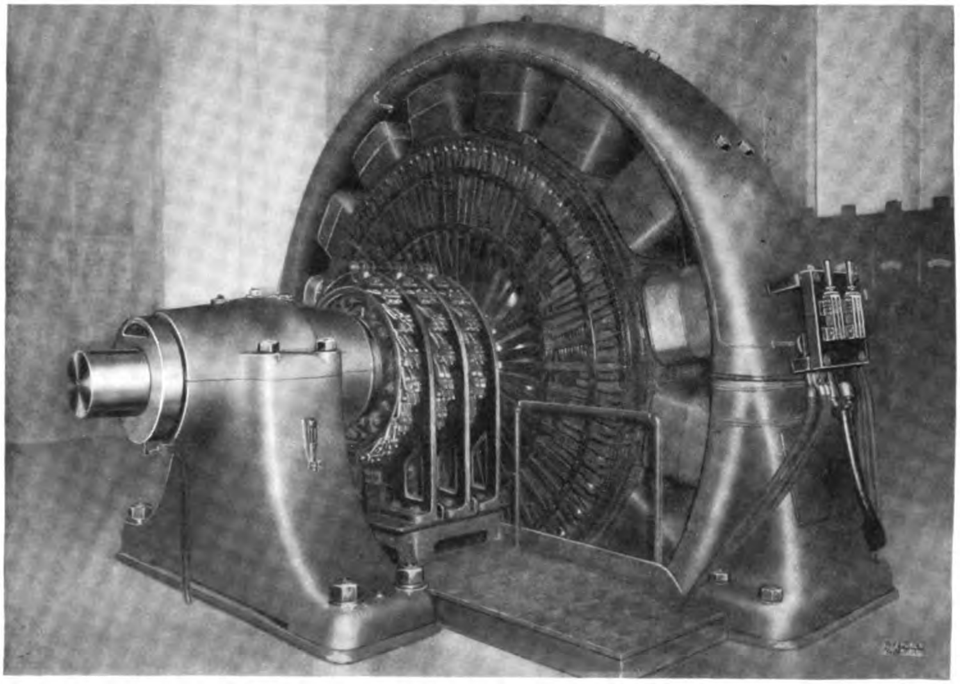

Fig. 1. 16 Pole, 2000 Kw., 188 R.P.M., 600 Volt Six-Phase Rotary Converter

The apparatus required can also be reduced to the smallest number of different elements by the adoption of certain standards, especially as regards voltages, machine capacities, switchboards, and details of arrangement affecting design, such for example as the location of terminals, with resulting advanages to both purchaser and manufacturer.

The purpose of this article is to present the results of years of experience in railway substation practice, and to give the standard voltages and capacities of apparatus for railway substations which have been adopted by the General Electric Company.

The subject will be presented in the following order:—

1. Standard transmission voltages.
2. Standard features of apparatus.
   - (a) *Converters*
   - (b) *Transformers*
   - (c) *Reactances*
   - (d) *Blowers*
   - (e) *Cables*
   - (f) *Switchboards*.
3. Typical station designs and details.

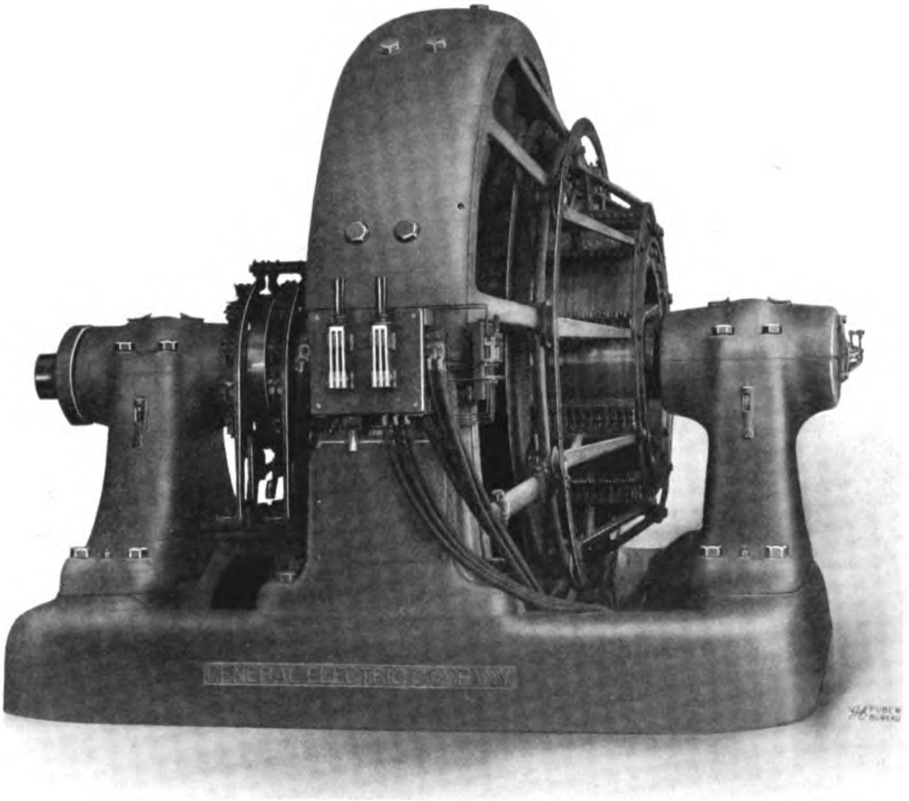

Fig. 2. 10 Pole, 1500 Kw., 300 R.P.M., 575 Volt Six-Phase Rotary Converter

STANDARD TRANSMISSION LINE VOLTAGES

The following three-phase voltages have been adopted by the General Electric Company as standard for railway work:—

11,000 volts with delta connected transformers.

19,100 volts with delta connected transformers.

33,000 volts "Y" or delta connected transformers.

57,000 volts "Y" connected transformers.

These voltages step up in the ratio of the square root of three to one, allowing the voltage of any system to be raised in case of extensions from one standard to the next higher by changing the transformer primary connections from delta to "Y." The lowest voltage (11,000), is the only one suited for direct generation without step-up transformers and is generally so installed. Such systems are not readily changed over, for which reason 19,100 volt transformers are delta connected only. On account of the prevailing use of 13,200 volts, transformers and switching apparatus can be supplied for this voltage also.

A frequency of 25 cycles per second has been adopted as the standard for railway work, 60-cycle apparatus being obtainable for railways fed from lighting or other 60-cycle systems.

Substation Apparatus

With the exception of cases where the alternating voltage must vary between unusually wide limits, or where the substation machinery must be used to correct low power factors of other parts of the transmission, rotary converters with transformers are preferable to motor-generator sets owing to their lower first cost, better efficiency, and simpler operation.

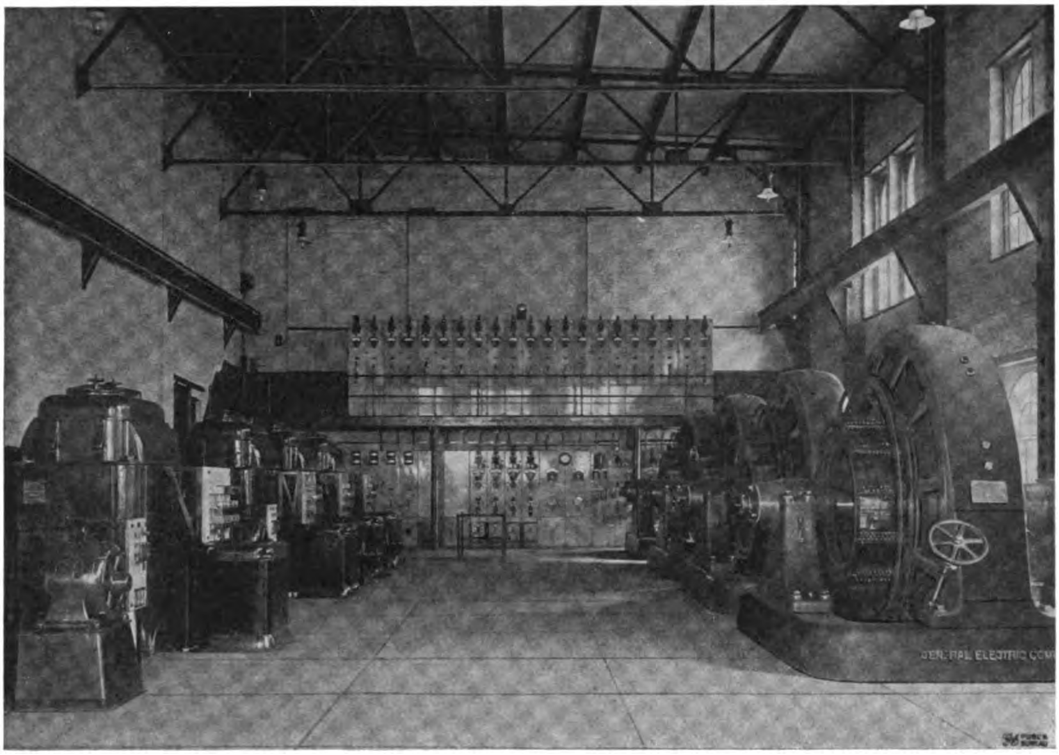

Fig. 3. Virginia St. Substation of the International Railway Co., Buffalo, N. Y. 1000 Kw. Converters with Three-Phase Air-Blast Transformers

Converters

Standard rotary converters have been developed for 25 and 60 cycles. The standard railway machines are compound wound, the series field being designed for a compounding of 600 volts at no load and full load, when supplied from a source of constant potential with not more than 10 per cent. resistance drop and with 20 per cent. to 30 per cent. reactance in the circuit. The 200 and 300 kw. 25-cycle converters and the 100 and 200 kw. 60-cycle converters are wound for three-phase operation, all the larger machines being wound for six phases.

Foundations

The standard rotary converters up to and including the 1500 kw. size are supplied with cast iron bases of the type shown in Fig. 2. These bases make the machine self-contained, but it is nevertheless advisable to grout under all of the edges of the base so as to avoid undue strains. No holding down bolts are required for machines with cast bases and no holes are provided for such bolts.

With converters of over 1500 kw. capacity the pillow blocks and field frames are carried by sole plates which should be supported on a suitable foundation. The 1000 kw. and

1500 kw. converters can also be furnished without base frames, but with sole plates.

Compounding of rotary converters is desirable where the load is variable, such as is the case with interurban railway systems. The purpose of the compounding is to compensate automatically for the drop due to line, transformer and converter impedances. On account of the low power factors caused by over compounding, and the fact that substations are customarily connected to the trolley at its nearest point without feeder resistance, over compounding is not recommended. An adjustable shunt to the series field is provided with each machine.

Shunt wound converters are entirely satisfactory for substations in large cities and similar installations where, due to the larger number of car units demanding power, the load is more nearly constant.

The Ratio of Conversion between the alternating and direct current voltages varies slightly in different machines, due to differences in design, and the best operating conditions exist when the desired direct current voltage is obtained with unity power factor at the converter terminals, when loaded.

The three and six phase machines require different voltages from the transformers, on account of the use of the diametrical connection instead of the double delta for six-phases. The no-load A.C. voltages delivered from the transformers and best adapted to compound converters designed to give 600 volts D.C. with a variable load, are 370 for three-phase converters and 430 for six-phase. This gives a lagging current at no load, a leading current on overloads and unity power factor at about average load.

Method of Starting

Three methods of starting rotary converters are feasible; first, the application of alternating current at reduced voltage to the collector rings; second, starting the machine as a D.C. motor; third, the use of an auxiliary starting motor mechanically connected.

The alternating current starting method has so many advantages over the other methods that it has been adopted as the standard by the General Electric Company. This method of starting is self-synchronizing, and therefore entirely eliminates the difficulty of accurately adjusting the speed under emergency conditions when the speed of the prime movers is liable to be variable. The ability to start a machine quickly and get it on to the line in the shortest possible time is a very great advantage inherent to this method of starting. It is possible for the converter to drop into step with its direct current voltage reversed from that of the bus to which the machine is to be connected, but the machine can easily and quickly be made to drop back a pole by a self-exciting field reversing switch on the machine frame. This method of starting makes the operation so simple that confusion and mistakes are greatly reduced under emergency conditions. As the apparatus used for starting is the same as that used for running, there is no need of any duplicate means of starting, thus reducing complications and simplifying operation.

The three-phase converters are started from one-half voltage taps in the transformer secondaries by means of suitable starting switches, and take approximately full load current from the line. The six-phase converters are started from one-third voltage taps and take three-quarters to full load line current. These currents are less than the usual railway load fluctuations and are indistinguishable from such fluctuations at any point of a loaded system. At light loads the effects of starting converters are more perceptible, but are quite negligible on apparatus capable of carrying the railway load fluctuations of the converters when running.

On account of the fact that 60-cycle converters take somewhat greater starting currents than 25-cycle converters, and are generally run from lighting systems where small voltage disturbances are more serious than on railway systems, methods for starting from either the alternating or direct current side are usually provided with such converters.

A motor-starting arrangement is considered undesirable on account of the complications introduced, without any compensating advantages.

Direct Current Connections

Single-pole switchboard panels are used, the positive main bus bar being the only one on the board. The negative terminals are connected without switches to the negative or ground return bus bar, which may conveniently be located beneath the converters. The series field is connected in the negative side, and the equalizer, series field, shunt and field break-up switches are all located on the machine frame as shown in Fig. 2. The purpose of the latter switch is two-fold; first, as stated above, to reverse the direct current polarity when the machine drops into step with the polarity wrong; and second, to open the field circuit at starting. In order to reduce the induced voltage strain upon the field insulation when the machine is started from the alternating current side, this switch is made with four poles to break up the field circuits.

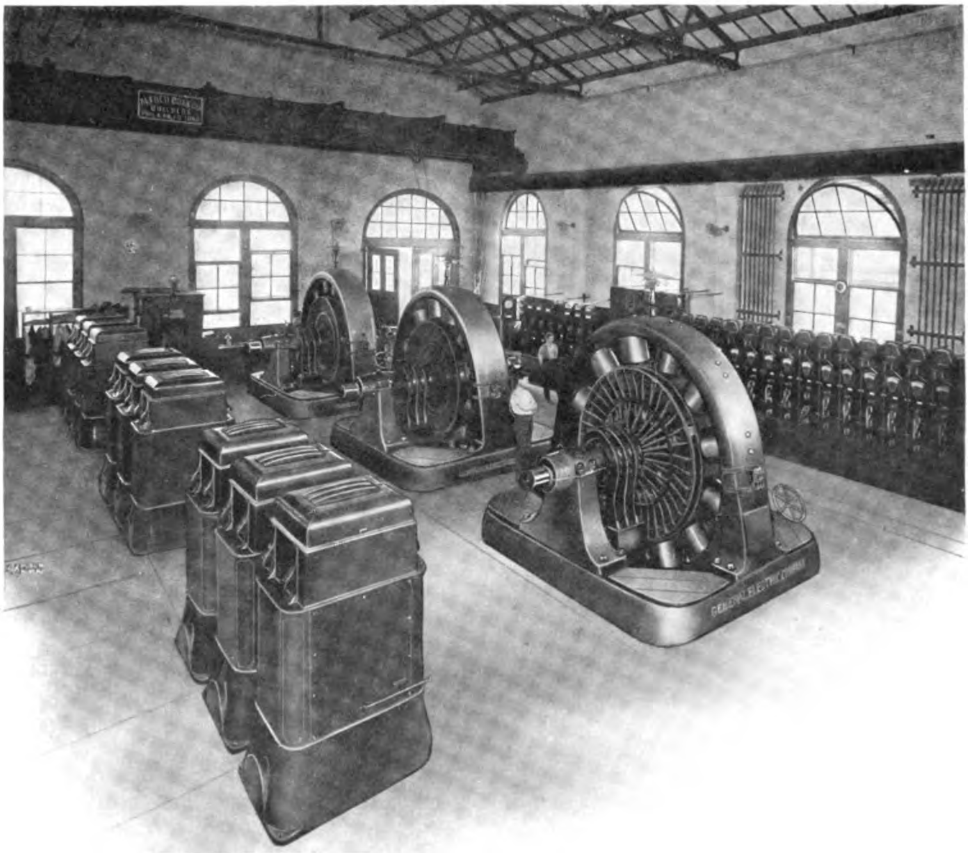

Fig. 4. Interior of the Palisade Substation of the Public Service Corporation, Newark, N. J. 1000 Kw. Converters with Single-Phase Air-Blast Transformers

These switches are mounted on the left hand side of the frame as viewed from the commutator end. This location should be kept in mind when arranging substations with the switchboard at one end, as these switches should be on the side of the machines toward the switchboards.

Mechanical Devices

A speed-limiting attachment, which automatically opens the direct current circuit breaker when the speed of the machine exceeds a predetermined value, is attached to the converter armature shaft on the collector ring end. This device is to provide against possible damage from excessive speed such as might occur when the alternating power is off, and energy, returning either through the direct current feeders or from a storage battery, causes the machine to run as a differential motor.

An end play device, or oscillator, is attached to the other end of the armature shaft to cause a slight reciprocating motion of the armature, thereby better distributing the wear of the brushes on the commutator and collector rings.

Transformers

Transformers are usually arranged on the unit system, that is, one bank of three single-phase or one three-phase transformer to each converter. These units are customarily of a rated capacity about 10 per cent. in excess of that of the converter.

The selection of the type of transformer is largely a question of individual opinion and local conditions, as all types are equally reliable.

Types of Transformers

General Electric transformers may be broadly divided into two classes, oil insulated and air blast. The latter are limited to work with a nominal line potential not exceeding 33,000 volts, and are perfectly satisfactory at this voltage, while the former may be used for higher voltages.

Table showing types of transformers available for standard converters, and customary rating of transformers.

Size of Converter	SINGLE-PHASE				THREE-PHASE		
	AB	H	OC	WC	ABT or ABH	HT	WCH
200		75				220	
300	110	110			330	330	
500	185	185			550		550
750	275	275			825		825
1000	365		365		1100		1100
1500	550			550	1650		1650
2000	735			735	2200		2200

Air-blast transformers are always made shell type and are supplied either in the single-phase or three-phase form, in sizes suitable for all standard 25-cycle converters except the 200 kw. size. Their use is recommended particularly in large sizes where water is not available for cooling purposes, since this condition makes oil-insulated transformers large and expensive per kilowatt in order to give sufficient radiating surface for cool running. This applies, of course, to a greater extent with large than with small transformers, since it is more difficult to make a large transformer self-cooling than a small one.

Oil-insulated transformers may be divided into three general types:

First. The core type self-cooling listed as type "H" for the single-phase form and "HT" for the three-phase form. (See table below.) These transformers may be obtained for any voltage up to about 350 kw. in capacity; that is, in the three-phase form for 200 and 300 kw. converters and in the single-phase form for all converters up to and including the 750 kw. size.

Second. The shell type self-cooling listed as type "OC," and supplied for standard converters in the single-phase form only, and in any voltage for the 1000 kw. converter. Above this size self-cooling transformers are not supplied as standard.

Third. The water-cooled type listed as type "WC" in the single-phase form and "WCH" in the three-phase form for six-phase converters. This type is made in 550 kw. sizes and larger and may be used for any voltage in the three-phase form for 500 kw. converters and larger; and in the single-phase form for 1500 and 2000 kw. converters.

Three-Phase Transformers as compared with three single-phase transformers of corresponding aggregate capacity have greater compactness, lighter weight and lower first cost.

Their use is recommended, except for stations with one converter where a spare transformer may be wanted, or in the largest sizes where the weight of the three-phase transformers may be excessive for handling purposes. In the self-cooling oil-insulated type "H" style, three-phase transformers are supplied only for 200 and 300 kw. converters, while single-phase transformers of the same style are supplied for larger converters.

Delta vs. "Y" Connections of Transformer Primary Windings

Delta-connected transformer primaries have been customarily used to permit operation with two transformers in case of trouble with the third. It has not usually been appreciated that, with the primary windings "Y" connected, with the neutral solidly grounded, and with the neutral of the generating system similarly grounded, either three-phase or six-phase converters may be started and successfully operated with two transformers per converter in case of trouble with the third. The output in either of the above emergency cases is, of course, limited to that of the transformers in use. With the grounded "Y" connections, the service may be maintained in case of trouble on one phase of the transmission line, the other two wires and ground serving as the circuit.

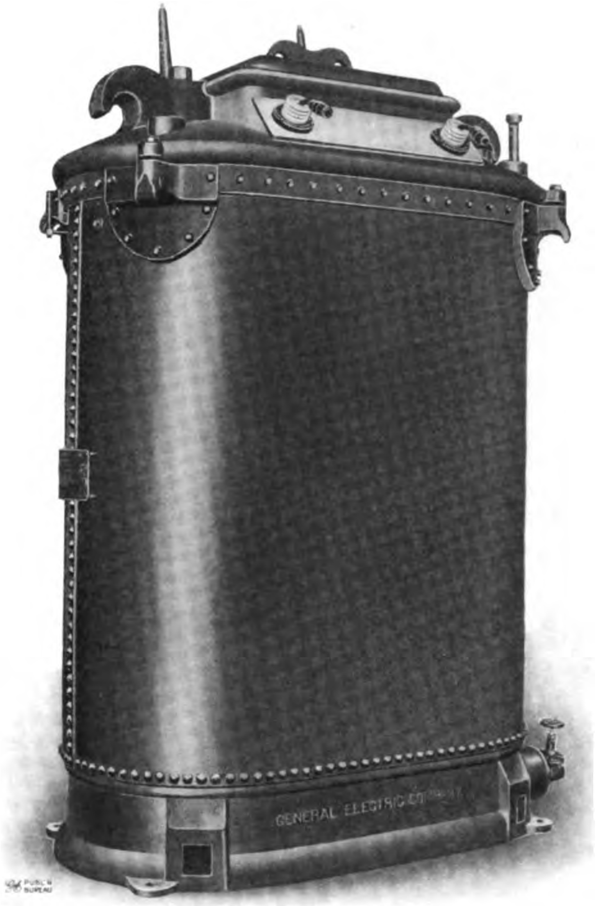

Fig. 5. Water-Cooled Single-Phase Transformer; 25 Cycle, 900 Kw., 7500 Volts Secondary, 30000/54000 Volts Primary

Should three-phase shell type transformers be installed with high tension delta or grounded "Y" connections, two phases may be likewise operated provided both windings of the third phase are disconnected and short circuited. The output of the unit is limited in this case to the capacity of the two transformers or phases, instead of the three. The three-phase core type transformer, rated "HT" in the table, cannot be operated should one phase become inoperative.

Transformer Options for Converters of Different Sizes

For 200 kw. converters, self-cooled oil-insulated core type transformers single or three phase (types "H" or "HT") are the only forms available, while for the larger sizes up to and including 1000 kw. self-cooled oil-insulated single-phase transformers may be used for any voltages; or air-blast single or three phase transformers may be used for any voltage up to and including 33,000 volts, the self-cooling becoming more expensive than the air-blast when the capacity is increased beyond a certain size.

Begining with the 500 kw. converter, the water-cooled three-phase transformers become available. For 1500 kw. and 2000 kw. converters, air-blast and water-cooled transformers are the only alternatives. Either may be three-phase or single-phase, the water-cooled alone being available above 33,000 volts.

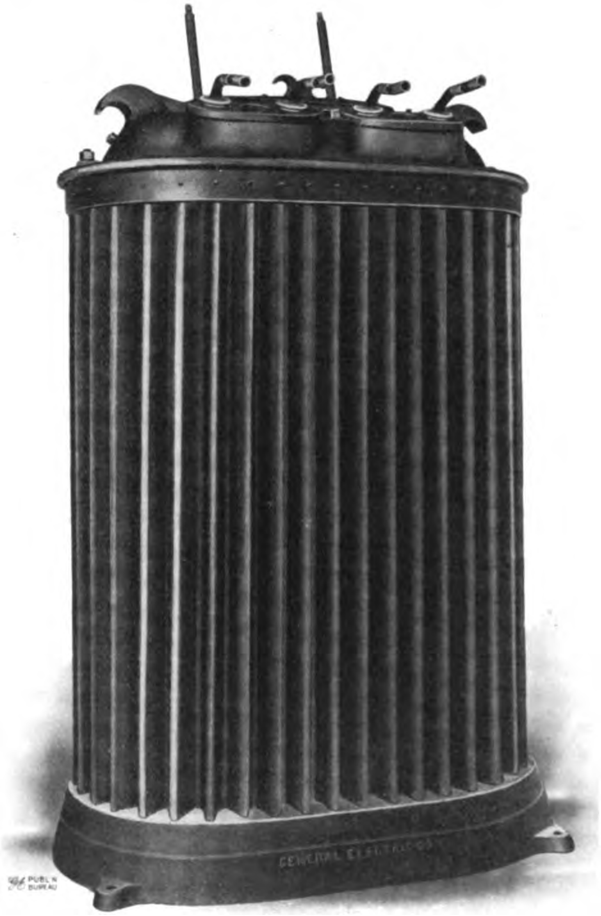

Fig. 6. Type H Oil-Cooled Single-Phase Transformer, 25 Cycles, 185 Kw., 19050 Volts Secondary, 33,000 Volts Y Primary

All railway transformers are supplied with taps on the primary winding to compensate for line drop and to provide a means of adjusting the alternating current voltage applied to the converter, so that the machine may be run at normal field excitation. There are provided four 2½ per cent. taps so as to allow for a drop of 10 per cent. Secondary starting taps are provided in all transformers.

In the rating of transformers the signification is as follows:

AB—Air blast shell type single-phase.

WC—Water-cooled oil-insulated shell type single-phase.

OC—Self-cooled oil-insulated shell type single-phase.

H—Self-cooled oil-insulated core type single-phase.

ABT—HT, etc.—Three-phase to three-phase.

ABH—WCH, etc.—Three-phase to six-phase.

All secondary windings are designed for delta connection for three-phase converters and diametrical connection for six-phase converters.

All oil-insulated transformers have both the primary and secondary leads entering through the top. All air-blast transformers have secondary leads issuing through the base and primary leads through top or base according to station requirements as outlined later. All air-blast transformers take air through their bases and are fitted with dampers to cut off the supply of air when out of service.

Reactances

To enable the D.C. voltage to be altered by the field rheostat or automatically by compounding, which calls for a corresponding change of the A.C. voltage, a three-phase reactance coil is provided between the low tension windings of the transformer and the converter. Without such a reactance it is impossible to give the same voltage at full load as at no load without excessive leading and lagging currents and consequently excessive heating in the converter armature, unless the resistance drop from the source of constant potential is small or the natural reactance of the circuit is unusually high. If the converter field is weakened, a lagging current is set up which causes a drop in the reactive coil. If the field is strengthened a leading current is set up which gives a rise of voltage in the reactive coil. Under heavy load, the series field of a compound converter tends to produce leading currents, which tendency is practically balanced by the reactance, improving the power factor of transformers, lines and generators when loaded. The standard reactances are rated in k.v.a. equal to 15 per cent. of the kilowatt rating of the accompanying converters. For instance, a 300 kw. converter is supplied with a reactance in each phase in which the full load current, 500 amperes, causes a reactive e.m.f. of 30 volts or approximately 15 per cent. of the delivered e.m.f. Thus a lagging current or component equal to one-third full load causes a 5 per cent. drop in the reactance coil, and a leading component of the current of the same magnitude causes a 5 per cent. boost or rise of voltage. Six-phase converters use three-phase reactances with twice as high a voltage drop at full load.

Either the air-blast or oil-cooled type of reactance may be used for rotary converters of any capacity, with the exception of the 200 kw. converter, for which oil-insulated transformers and reactances only are available. Air-blast reactances should be used with air-blast transformers, and oil-cooled with oil-insulated transformers of either the self-cooling or water-cooled type.

All leads to and from oil-cooled reactances enter the case through the back near the top. Air-blast reactances are bottom connected. Air-blast reactances take air through their bases, and are fitted with dampers for cutting off the air supply when out of service.

Blowers

Air-blast transformers require a pressure varying between one-half ounce per sq. in. for the small sizes and one ounce for the large sizes. A line of blowers especially adapted to meet the conditions; that is, large volume and comparatively low pressures, has been developed for this class of work. Standard blower sets consist of left-hand, down-blast, steel-plate fans direct connected, and driven by three-phase induction motors wound for the secondary voltage of the transformers.

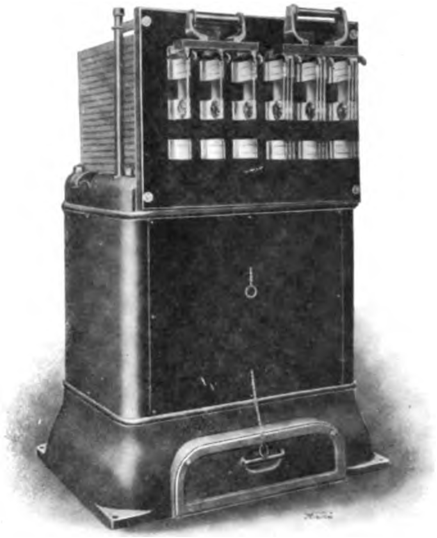

Fig. 7 Three-Phase, Air-Blast, Form "D" Reactance; 25 Cycles, 300 Kw., 60 Volts, 1667 Amperes

For all installations of more than one converter, it is recommended that duplicate blower sets be installed, and that each fan have sufficient capacity to supply air for all of the transformers and reactances in the station with 10 per cent. margin for air-blast chamber leakage. In case, however, the total requirements are greater than 10,000 to 15,000 cu. ft. per minute, three blower sets should be installed, any two of which should be capable of supplying the total amount of air required.

Cables

For the 600-volt connections to the switchboard, and all secondary connections from transformers to the converters via the reactive coils and starting switches, the General Electric Company recommends the use of varnished cambric cable, manufactured for working voltages of 1000 volts or less, with asbestos braid and not lead covered. This may be run in porcelain cable cleats, if the substation has a basement, or in ducts; or in the case of the D.C. cables, in iron pipe.

Switchboards

The switching apparatus for this class of work has been simplified to the smallest number of elements, retaining every switch and instrument essential for convenient and reliable operation. The standard switchboard panels are as follows:

A.C. Main Panels:

(1) Incoming line panel.
(2) Outgoing line panel.
(3) High tension converter panel.

D.C. Main Panels:

(4) D.C. converter panel.
(5) D.C. feeder panel.

In addition to the above, there are various auxiliary panels not usually incorporated in the main switchboard, including A.C. starting panels, blower motor panels and control storage battery panels. The latter are used for 125-volt storage batteries, which are required for the operation of motor-driven oil switches. The above panels, excluding the auxiliary panels, are with certain exceptions 16 inches in width and 90 inches in total height, divided into three sections each. The exceptions are D.C. converter panels for 1500 and 2000 kw. machines and D.C. feeder panels of 4000 ampere or greater capacity, all of which are 20 inches in width; also double circuit D.C. feeder panels equipped with two ammeters, which are 20 inches in width.

The standard material and finish are dull black oiled slate, with instruments finished in lustreless black lacquer. All instruments are proportioned to indicate 100 per cent. overload, and all switches, current transformers, circuit breakers, etc. will carry a 50 per cent. overload of their corresponding machine or circuit continuously. All panels are supported on steel pipe frames with suitable attachments for the support of bus bars, field rheostats, etc.

D.C. Switchboard Details

As above-mentioned, all D.C. converter panels are single-pole and of positive or trolley polarity, so that the switchboard bus bar is continuous from the converter to the feeder panels, which are usually adjacent. The equipment of a standard D.C. converter panel comprises:

One carbon break circuit breaker with overload and low-voltage release. (The latter connected to the speed limit device.)
One illuminated dial ammeter with shunt.
One field rheostat.
One two-point potential receptacle.
One single-pole main switch.
One single-pole, double-throw station lighting switch.
One Thomson recording wattmeter. (Optional.)

The General Electric Company recommends the use of one such wattmeter per machine in preference to one bus bar wattmeter, on the score of better wattmeter load factor, readier calibration, easier extension of station capacity, etc. The station lighting switches are tandem connected to enable the lights to be supplied from any converter, on the machine side of its circuit breaker. The potential receptacles connect to one illuminated dial D.C. voltmeter on a swinging bracket, usually mounted at the end of switchboard.

The D.C. feeder panels are each equipped with an overload circuit breaker, ammeter, main switch, lighting arrester and choke coil; also one potential receptacle per feeder, by means of which the feeder voltage may be determined with the circuit breaker open in case the feeder is tied through to another substation.

A.C. Switchboard Details

The equipment of the A.C. panels depends somewhat upon the form of switch adopted, whether hand or electrically operated. In general, however, one ammeter is recommended on the converter or incoming line panels and three ammeters on the outgoing line panels, with automatic overload operation of the switches from one current transformer in the case of incoming line or converter panels, and from three current transformers in the case of outgoing line panels.

With hand-operated switches the overload actuating devices take the form of tripping coils combined with the switch handles, while for electrically-operated switches overload relays are used.

Switchboard Arrangement

In general the D.C. switchboard panels are arranged in a group by themselves, converter panels to the left and feeder panels to the right, with room for an extension of the converter panels to the left and feeder panels to the right. No attempt is made to group the oil switches, either hand or electrically operated, behind the main switchboard, the oil switches being invariably, in the more recent types of construction, located immediately adjacent to their banks of transformers or line entrances, or exits, as the case may be. For all stations using hand-operated switches, this makes it advisable to locate the A.C. line and high tension converter panels in a corresponding position. With electrically-operated switches there is no definite relation between the location of panel and switch, and in this case it is customary to locate the A.C. line and high tension converter panels in line with the D.C. switchboard. No incoming line panels are used unless the lines are in duplicate, a single incoming line being tied to the substation bus bars without oil switches.

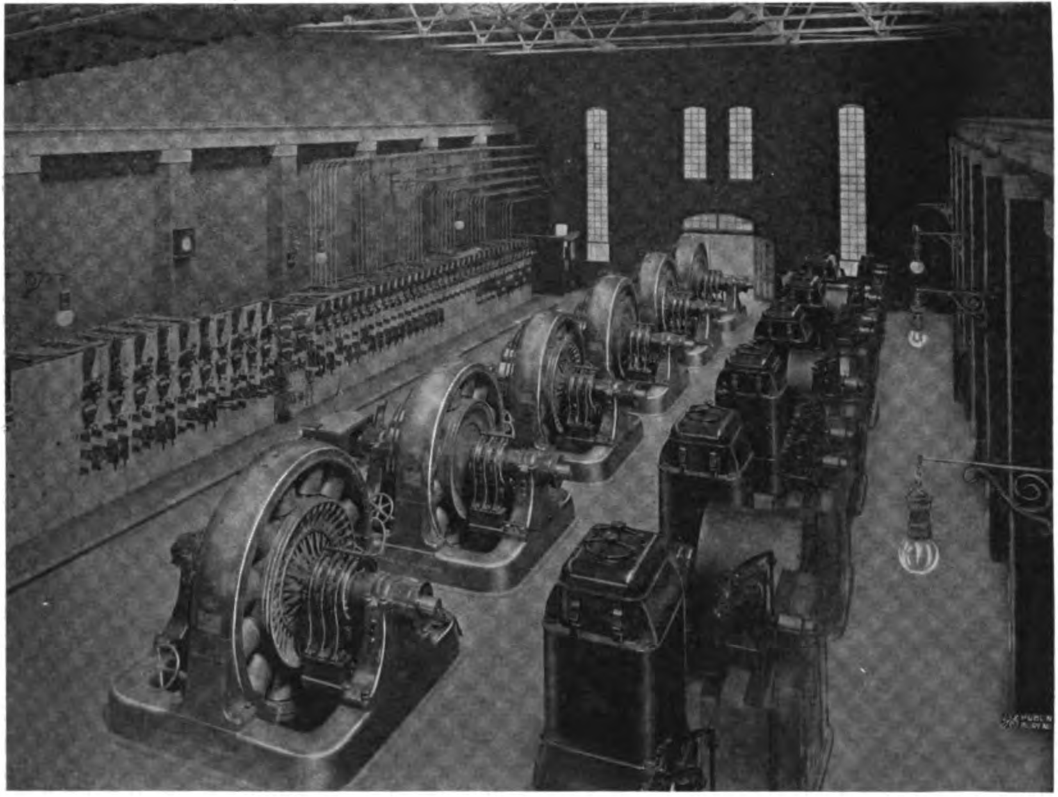

Fig. 8. Interior View of Locust St. Substation, United Railway Co., St. Louis, Mo. 1000 Kw. Converters with Three-Phase Air-Blast Transformers

General Arrangement of Substation Apparatus

From the above it will be noted that the arrangement of the apparatus in the substation is largely dependent upon the nature of the switching equipment. The following are further features of the switching equipment which intimately affect the station design.

Form "K" or hand-operated switches are invariably top connected, making it convenient to locate high tension bus bars above such switches; the high tension switches of the transformer and converter units being located immediately back of the corresponding three-phase transformers or three-phase groups of single-phase transformers. The line switches, if there are any, are located in line with and between the converter switches, the corresponding high tension panels being located in front of their respective oil switches and on the operating side of the transformers. For relatively large substations containing converters larger than 300 kw., or more than two converters, the division of the station by a wall between transformers and switches is recommended, with a crane spanning the converter and transformer room.

On the other hand, to suit a case with incoming high tension three-core cables underground, and motor-operated switches, these switches are bottom connected, making it convenient to locate bus bars and all high tension connections below the floor in a suitable compartment in the basement. The connections from the high tension converter switches to the transformers pass through the partition wall between the high tension compartment in the basement and air-blast chamber, the transformers in this case being bottom connected, that is to say, having both the high and low tension leads brought through their bases. This case also illustrates the above-mentioned arrangement of all main panels both A.C. and D.C. in one switchboard.

MISCELLANEOUS RECOMMENDATIONS

Ventilation

It should be borne in mind, in laying out a station, that even the normal operation of the machines will considerably increase the temperature, and some provision should therefore be made for good ventilation. This is particularly important where oil-cooled transformers are used and ample ventilators should be provided in the roof so that the temperature will not become unsuitable in the summer time. It is unnecessary to provide any auxiliary means of heating in compact substations which carry a station load factor equal to average practice, and which run 24 hours per day.

Drainage

Where air-blast transformers are used the walls of the air-blast chambers should be waterproofed and the substation built at such an elevation that water will not stand on the floor of the air-blast chamber. If this is not done the transformers may be damaged by the warm air from the blowers picking up moisture and depositing it in transformers which are not in service.

Where any cables come into the station underground the entering conduits should be sealed and suitable drainage provided so that water cannot leak into the cellar through these openings. When oil-cooled transformers are used it is well to install a pit of sufficient capacity to hold the oil from several transformers, and to provide drainage piping from the oil drain cocks on the transformers to the pit. This pipe should be of ample size so that the oil can be drawn off very quickly in case of emergency.

Crane

It will generally be found that the installation of a crane is justified not only for its convenience but on account of the actual economy of building floor area which is possible with its use. To get apparatus to the doorway, the space between machines, switchboards, etc., must be great enough to allow the largest piece to pass when laid flat on the floor, if no crane is provided. These pieces, such as rotary converter bases, etc., may be carried edgewise when a crane is used, and the saving effected often offsets the cost of the crane. The possible saving of time, when it becomes necessary to work on machinery rapidly, need hardly be mentioned, and the value of a crane at such times is obvious.

Air Supply for Blowing Out Apparatus

An air compressor is an item which should never be overlooked in a substation of any considerable size, as the life of any electric apparatus depends to a very large extent upon its cleanliness. It is generally most satisfactory to install a compressor similar to that used on one of the cars, and to furnish a storage tank capacity of about ten cubic feet. The air should be piped from this tank to various points in the substation where cocks should be provided for the attachment of a rubber hose. An air-pump governor provides a convenient means for keeping the air in the storage tanks at constant pressure.

Conclusion

The recommendations presented in this article are based on experience and have proved satisfactory in actual practice. This information is presented with the hope that it will be found of value to electric railway managers and engineers, and that they will co-operate in effecting a more complete standardization of substation design and railway transmission potentials.

A RETROSPECT

By Prof. Elihu Thomson

In this age of special tools, highly developed machinery and processes of construction, when materials are available with properties covering the widest range, it may possibly be useful or instructive to turn back to the time of the inception of the electrical engineering art and review the conditions as they existed approximately thirty years ago. Such a retrospect may assist those who have not had an opportunity to acquire a just perspective, and may help towards the appreciation of the better conditions which now exist for accomplishing work on a satisfactory basis, or for embodying ideals which, even if existent in the early days, were not accompanied by the means for execution.

One has only to visit the shops of a large electric manufacturing concern of to-day, and to notice the great variety of stock or material found in store in its stock-rooms, to be impressed with the fact that modern results come about by a combination of highly developed organization and methods. As an example, one may watch the elaborate machinery in the form of punch-presses and the like, which have to deal with the manipulation of sheet-iron or steel entering into the armature cores of dynamos and motors, without realizing that all of this development is but recent. There was a time in the art when it would have been futile to have made a design, however meritorious it might appear, involving the use of punched sheet metal in complex forms, for neither the material of proper quality existed, nor was the machinery for giving it the proper shape available.

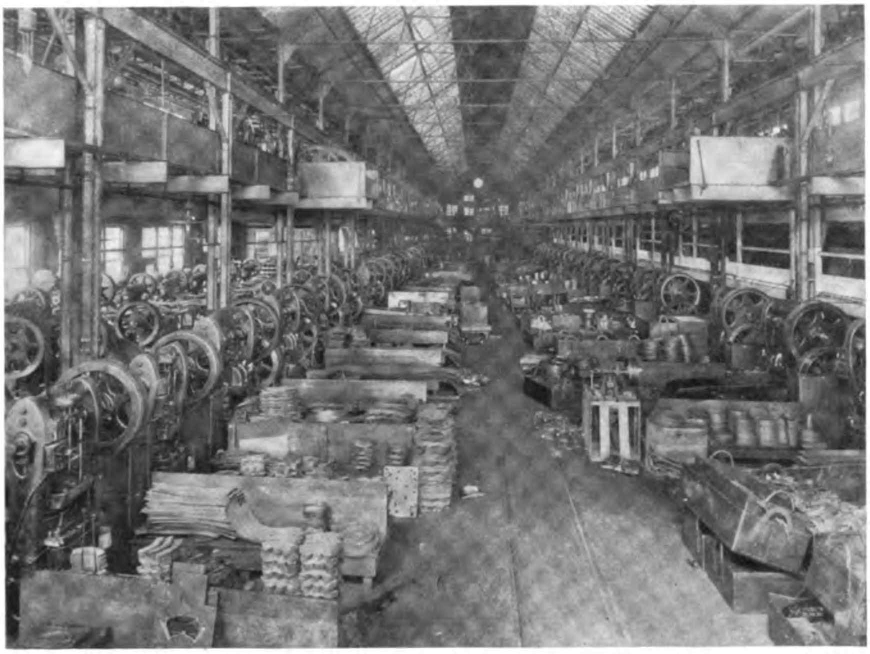

Fig. 1. Punch Press Department, Schenectady Works, General Electric Company

In the early days of the electric industry the cores of dynamo armatures were commonly made of iron wire wound up into rings on cylinders; or, in other cases, of plates or forms of cast iron. When sheet iron was used it was generally in the form of heavy plate, cut out by crude machine processes or laboriously worked out by hand. The iron wire itself was not especially adapted to the purpose, and varied widely in its qualities, whereas about the only available sheet iron was stove-pipe iron, or the sheet iron from which sheet-iron utensils were made, and, of course, the existence of magnetic losses was not taken account of in its manufacture. The early worker had to put up with what he could get instead of what he wished he could have. He had to bend his designs and constructions to the use of such materials as were available, and the selection being a most restricted one, it will easily be understood that there was little freedom in designing in those early days. At the time referred to, cast iron was mostly used for magnet frames, although occasionally wrought material was employed. One had to put up with simple forms of the latter and with whatever quality of iron the foundry (generally a separate organization) happened to furnish. Steel castings now enter widely into electrical construction.

Even in the case of copper wire the limitations were severe. It was not obtainable in long lengths without joints or the necessity for making them. It was imperfectly drawn, frequently having slivers projecting through the insulation, and often varied in shape of section from round to oval; and the amount of the section varied. Round wire only was available for use. There were no square or rectangular sections to be had. Fine wire was not then drawn through jewels, and a coil would vary in section from one end to the other, owing to the wear of the dies. With the shunt magnets of series arc lamps it was sometimes quite necessary, in order to obtain any definite resistance in the coils with a given number of turns, to combine wires which varied in such a way that a portion of the coil would be of smaller section and another portion of the coil of larger section so as to get somewhere near the desired average section.

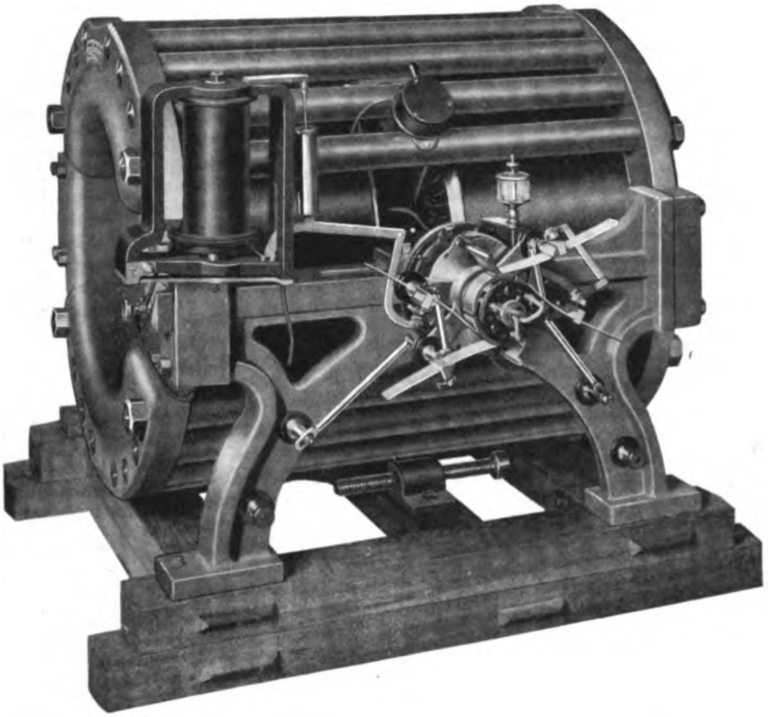

Fig. 2. Thomson-Houston Arc Light Dynamo, Showing Regulator and Brush Mechanism

The designer or constructor was equally limited in the insulation which was available. Generally, he found that he had to rely upon paper or cloth for insulation, with shellac varnish. The paper itself was liable to be defective, as it might contain particles of iron or other metal, or bits of carbon, in case the paper mill was near a railroad. Mica was not at first available, its use being practically limited to clear and relatively very expensive sheets for stove doors, and the forms of colored and soft mica now so commonly found in use were not then mined, as there was no market for them. Flakes of mica, pasted upon paper by shellac and overlapping each other, were first used in the Lynn Factory in 1883 or 1884 and formed the first built-up mica employed. The sheets so built were used to separate the coils of arc light dynamo armatures. Insulation between commutator segments was originally shellaced paper, vulcanized fibre, or some similar substance, afterwards replaced by mica. The mica cone insulations for commutators came later, being some of the first mica pieces which were built up from flakes or out of small pieces, all of which were held together by varnish and heated in forms.

Very early commutators and other parts of machines were insulated with red fibre or vulcanized fibre, even then a manufactured product. It varied greatly, however, and was treacherous, as the process of production did not always remove the acid of chloride of zinc used in the treatment of the fibre. Defective material of this kind was the cause of many breakdowns. Reliance had to be placed upon wood, even for such things as switch supports and fuse boxes—as there was no electric porcelain manufacture; and even slate itself was not used, being unavailable, or not to be found readily on the market in suitable form.

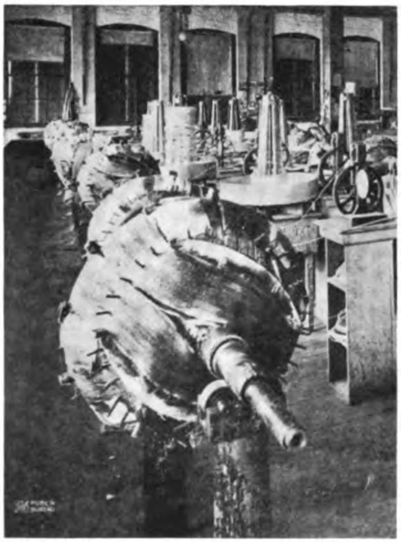

Fig. 3. Smooth Core Armature in Process of Winding, Showing Wooden Pegs for Holding Coils in Place

At the time of the early introduction of arc lamps for street lighting and for interior lighting, the arcs were frequently burned bare, without globes or any other enclosure. Sometimes clear globes were used, and occasionally opal ones, but thin opal glass could not be obtained then, and the globes were made of heavy dense opal glass and absorbed about 60 per cent. of the light. The globes were also frequently misshapen and varied greatly in thickness. The carbons used in the working of the arc lights were also very imperfect at the start, many of them being so crooked that they would not stand opposed to each other without sliding by one another. The methods of manufacture had not been so fully developed but that a large proportion of the product was defective in straightness. Similarly in the chemical constitution of carbons, and in the heat treatment or baking, great variations occurred. Very often there were impurities present which caused the arcs to flame and sputter or hiss at intervals, while some carbons would burn out in much shorter time than others. For a time indeed, the question of getting satisfactory carbons was a very vital one in the development of arc lighting.

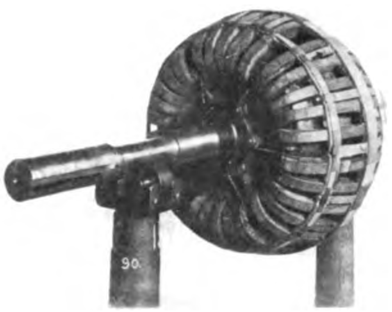

Fig. 4. Armature of Thomson-Houston Dynamo for Incandescent Lighting

Twenty-five to thirty years ago the only lines outside of telephone and telegraph lines, which extended any distance away from the station, were those for series arc lighting, and were generally of bare copper mounted on telegraph insulators. One of the first high tension experiments, and one which ended with some disastrous consequences, was the coupling of seven 40-light Brush arc light machines in series on a single bare wire circuit in Cincinnati, at the inception of the arc station there. The idea of high voltage apparently had not penetrated the consciousness of the people in charge of the installation, for it is said that immediately on starting up, several of the machines burned out. The total potential of the line would have been some 14,000 or 15,000 volts, and no special precaution had been taken to insulate for this relatively high pressure.

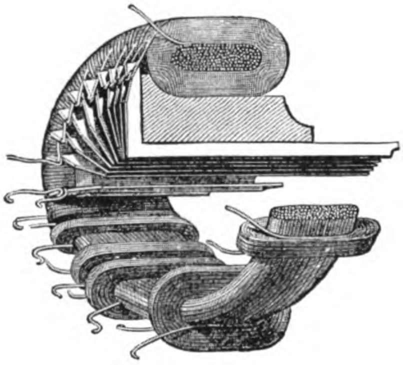

Fig 5. Gramme Ring Showing Core Made Up of Iron Wire

Wherever in the early years, the factory building was not badly suited to the purposes of the business (as was too often the case), it generally happened that the engine power was either deficient or badly governed, or that the boiler capacity was much too small for the engine; while frequently the testing of dynamos had to be made at a distance from the engine itself involving several belt transmissions. It will be readily understood that, with a slow-moving engine, badly governed, and such belt transmission, testing, under anything like standard conditions, was practically impossible. The modern engine of comparatively high speed did not then exist, and the governing, which was good enough for most of the ordinary factory uses, was, of course, very defective for the demand of steady driving of electrical machinery. Along with the development, therefore, of electrical applications, it was a matter of necessity that engine power should follow and become more and more refined.

Not only was there difficulty in obtaining the proper power conditions in the manufacturing plant, but oftentimes the early electric station was in a building already existing and with an engine which had been given up for some other use and applied to the new demand, as an economy. Those were the days when arc light machines had frequently to be loaded up in the stations by lamps, making up for the deficiencies of the external or outdoor load; and it was not unusual to see 50 or 60 lamps or more burning in a station, consuming carbons merely as idle load to fill up circuits that did not have their full complement of commercial lamps. It was the unsatisfactory engine power and transmission by belts and the variations of load conditions which led us early to the adoption of means of regulation for constancy of current in arc machines or circuits; a remedy which practically accomplished all at one stroke. It made the circuit independent of the variations of engine or of its governing, and independent of the variations of load external to the machine.

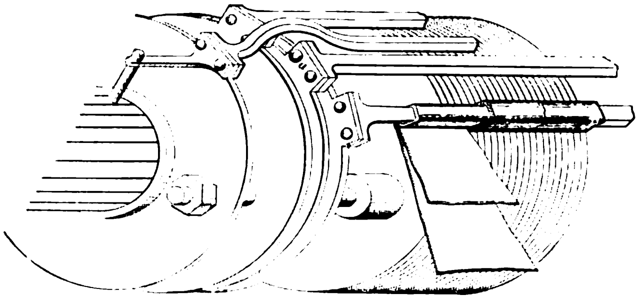

Fig. 6. Construction of Armature of Edison "Steam Dynamo"

At the inception of what is now the modern electrical industry, it was practically impossible to find suitable instruments for measuring the values of current or potential; the only measuring instruments to be found were those of the cabinets of natural philosophy and of the telegraph systems. Such instruments of measurement as tangent galvanometers, astatic galvanometers, etc., depending upon the strength of the horizontal component of the earth's field did not work very satisfactorily when masses of metallic iron were nearby, or when, as in one instance within my knowledge, locomotives passed by on adjoining railway tracks or loaded cars stood on the tracks not far away. Even the instruments themselves were not adapted to the currents or potentials in use, and it was necessary, therefore, for the pioneer to construct his instruments to obtain such information as was needed. In fact, many of the early workers evidently got along without any information obtained from measurements of current and voltage. It may be said truly that it is not more than thirty years ago since any consistent investigation of measurements of the currents, voltages, and efficiencies of dynamo machines were made. In view of this fact, it is even in a measure extraordinary that some of the early work succeeded as well as it did, especially in the field of constant current generation which, as is well known, demands certain dynamo characteristics in order that the current shall be stable or not subject to surging or oscillation. The data for design was very meager, and the work had to be done by a sort of sense of what was needed; a feeling, as it were, that certain proportioning between armature and field would be required to make a successful machine.

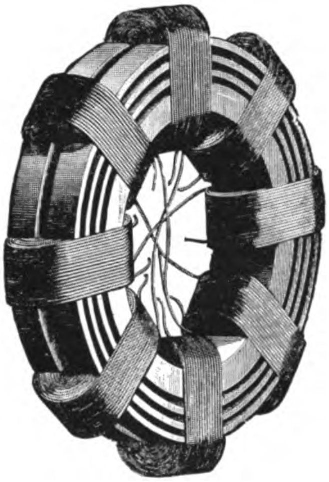

Fig. 7. Brush Armature with Its Coils in Position, Showing Unlaminated Core

In those days, too, the functions of the designer, inventor, engineer or electrician were very widely varied. He might partake of the work of works manager, salesman, patent expert, head draftsman; be engaged in construction and testing, and have various other functions more or less accidental or necessary. Also he had frequently to work under very great stress as to speed in getting work in shape. It might even be necessary that the plans and designs for a new size of dynamo should be ready within a day or so, and this frequently led to his work being continued through the day and night. The only system that then existed was to get the thing done as promptly as possible, and anything which would in the least have interfered would have been swept out of the way ruthlessly. The important consideration was that a certain thing was needed at a certain time, as vital to the business, and therefore conditions should be controlled to obtain the desired result. Experimental or new work had frequently to be done in the open shop. There were no special experimental departments and, of course, such work was carried on often to the detriment of the actual commercial work. This was also a necessity of the case.

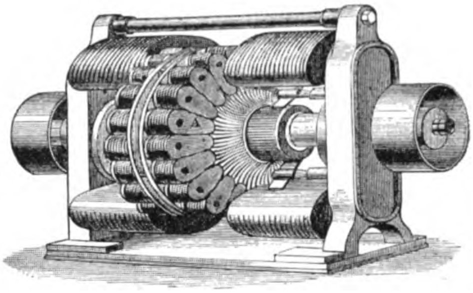

Fig. 8. Wallace-Farmer Machine

Oftentimes the machine equipment was —as in lathes, planers, etc.—so restricted that the designs had to be adapted, as it were, to the restricted manufacturing equipment. For example, work that ought to have been taken with one cut on a large planer was very frequently made on a small machine by turning the work about to make the separate cuts; and the designs of apparatus were frequently made to avoid the use of tools which did not exist, or which existed in very restricted size or number. This aspect of the subject can hardly be realized to-day unless one has had practical experience under the conditions. Doubtless some of the products of the early work seem from present standpoints to be very crude, and perhaps unnecessarily so, but this was often to be explained by the very fact that the equipment could not have met the demands of more perfect designs.

Dynamo armatures in the early days were mostly of the smooth core pattern, as these seemed to work more satisfactorily than forms which were made with projections. How completely conditions have changed in this respect may be seen by examining any of the forms of modern machines. In fact, the materials and means for using them were so imperfect and crude in the early days that armatures with projections obtained the reputation of giving bad commutator sparking, and so were avoided as the plague for a time. Since the projections were generally coarse, they would also produce considerable heating and losses with solid pole pieces. With the growth of lamination in other directions, lamination of the pole pieces was the natural remedy.

Some of the vagaries of design in dynamos and other machines were due to certain ideas which acted as fetishes, and which have since disappeared. Such, for example, was the idea that a drum armature should be of very great length, so that the idle wire on the armature, that is, the wire over the ends, would be small in amount in relation to that which was along the side of the drum. Other variations were due to patent conditions, preferred construction now open to all being subjects of patents then in force.

The brief outline given above could be amplified to almost any extent in the direction of showing the very great handicaps under which the early constructors labored, and the disadvantages which had to be met at every turn. The only advantage, perhaps, was the entire abandon with which new work could be undertaken and pushed to a conclusion, unhampered by matters or conditions which now sometimes complicate the process.

CURRENT TRANSFORMERS AS RELATED TO SWITCHBOARD DEVICES

By C. J. Barrow

Current or series transformers are a necessary intermediary between an alternating current circuit and various protective devices, meters, etc., when the voltage of the system is too high to be easily insulated and safely handled, or when the current is too high to be conveniently handled directly on such devices. Circuits in excess of 1100 volts should be supplied with current transformers, though certain apparatus designed for direct operation in 2300 volt circuits may be used in some cases. Ammeters, automatic trips, etc., of 300 ampere capacity may be had, but the maximum capacity obtainable in wattmeters and polyphase instruments is 150 amperes or less. In view of the above it is evident that current transformers will be used in all circuits of any considerable power; hence their performance and limitations under operating conditions are of general interest.

The series transformer is similar to a shunt transformer in having a laminated iron core and two windings insulated from the core and from each other. One of these windings (the primary) is connected in the main circuit, while the other (the secondary), which is well insulated from the first, delivers a current bearing a fixed ratio to the main current. The accuracy of the readings of all meters, etc., connected to the circuit will depend directly on the constancy of this ratio under varying load conditions.

Beginning with the main current in the primary as the source of energy, we have an alternating current circulating around an iron core and setting up a flux which induces in the secondary an opposing or demagnetizing current. The demagnetizing effect of the secondary current will always be somewhat less than the magnetizing effect of the primary, since some voltage is necessary to circulate the secondary current and must be generated by flux in the core. This flux in the core accounts for two components in the primary current which do not appear in the secondary —a magnetizing component necessary to energize the core, and a core loss component which supplies hysteresis and eddy current losses. Apart from these, the product of secondary current and turns equals the product of primary current and turns; and for a given primary current, that current most economically handled by secondary devices may be readily obtained by suitably proportioning primary and secondary turns.

Considering the components of the primary current more in detail, we have:—

1. That which magnetizes the core, a wattless component, varying with the flux density (volts across secondary load).

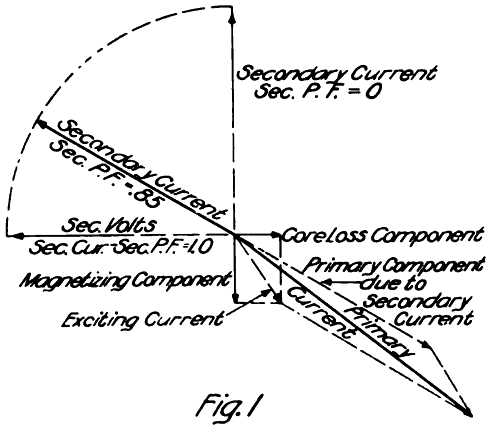

Fig. 1

2. That representing the losses in the core, an energy component, also varying with the flux density.

3. That which reappears in the secondary. Barring hysteresis, the flux will be in phase with the magnetizing component, while the counter e.m.f. of the primary and the e.m.f. of the secondary will lag 90 degrees. The core loss component, being an energy current, will be in phase with primary volts and will lead 90 degrees with respect to the magnetizing component. On non-inductive load the secondary current will be in direct opposition to the core loss current, but in quadrature with the magnetizing component; hence, with non-inductive secondary load, the ratio error is practically the result of the core loss component only. If secondary load is purely reactive, the current lagging 90 degrees from the voltage will be in direct opposition to the magnetizing and in quadrature with the core loss component, so the ratio will be influenced largely by the magnetizing component. Commercial loads usually contain both resistance and reactance, so both components will be active. These relations are shown diagramatically in Fig. 1.

The ratio error is compensated for by winding slightly less than the proportionate number of turns on the secondary. (Hence, a "step down" current transformer should not be used "step up.") An accurate ratio may be obtained in this way for given conditions of line current and secondary load, but with any variation from these conditions there is a change of flux, hence a change of magnetizing and core loss components which upsets the ratio. It is therefore necessary that these disturbing elements be reduced to a minimum, and to this end current transformer cores are worked at extremely low densities.

Low core loss and magnetizing components are further desirable that the phase displacement between primary and secondary currents may be as small as possible. The secondary current, being one of three primary components all of which are likely to be out of phase, may not be in direct opposition to the primary current (see Fig. 1). If the load is non-inductive, the secondary current will be in advance of direct opposition; if purely reactive, it will lag behind direct opposition. Somewhere between these extremes of load the two currents will be in direct opposition. Current devices will be subject to ratio error only, but devices operating with current and potential windings will be subject to both the ratio error and errors due to phase displacement.

Transformers are built in which these errors are negligible over the range for which the transformers are designed, but this range cannot be exceeded except at the expense of accuracy. The ratio will be maintained closely if the secondary impedance is such as not to require more than rated output at full load. As the impedance is increased the ratio increases, at first very slowly, but faster as the density increases; until at high densities, the high core loss, and particularly the high magnetizing components, represent a large part of the primary current, and the ratio therefore rises rapidly with increasing secondary impedance.

There is also an increase of ratio with decreasing primary current when the primary current is small (light line load) due to the fact that the magnetization curve at very low densities is the reverse in form of that at ordinary densities. That is to say, at low densities the permeability is less than at moderate densities. With primary current decreasing, the volts secondary, and hence the core flux, decrease proportionately; but since at this stage the iron is becoming less permeable, the magnetizing current does not decrease proportionately, and therefore represents an increasing proportion of the primary current. This feature limits the minimum desirable density, and calls for an iron of uniform permeability at low densities. This light load error should not be active above one-tenth load. Where the power involved is large and even a small percentage error means considerable, it is important that the ratio be accurate over the usual range of load, particularly at normal load and usual overloads.

The General Electric Company has standardized a secondary current of 5 amperes, with rated current flowing in the primary. This permits a standard line of secondary devices to be used with suitable transformers, on circuits of any capacity. A transformer is usually supplied having a current capacity equal to the momentary rating of the apparatus with which it is to be used. Under standard one or two hour overloads, such a transformer carries 3.75 amperes secondary; and if the transformer is rated 40 watts, the secondary impedance should be such as to require not more than 8 volts to circulate 5 amperes, or 6 volts to circulate 3.75 amperes; that is, the total secondary impedance should not exceed 1.6 ohms. In adding up the individual impedances of several pieces of apparatus constituting a secondary load, in order to get the total load on the transformer, the displacement between current and voltage in each device must be considered, and the vector sum of the voltages used.

To properly insulate the primary of the higher voltage transformers is a rather difficult problem, calling for the best of insulating materials and wide experience on the part of the designer. Between windings there is always the normal potential strain to ground, while during abnormally high frequency disturbances the primary, which acts as a choke coil, is very liable to break down between turns. To insure operator and secondary apparatus against a dangerous potential between low tension circuits and ground in case of failure of insulation between primary and secondary, the secondary winding should be permanently grounded. Even though well insulated, the secondary receives a charge, due to the static potential of the primary, which may be serious to the operator and apparatus unless relieved by a ground connection. On this account, also, the frame work of the transformer should be grounded.

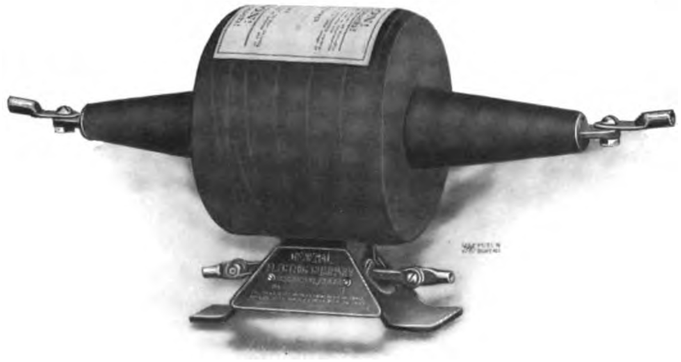

Fig. 2. General Electric Current Transformer

It is interesting to note that the open circuit secondary voltage of a transformer is determined by the frequency, secondary turns, and flux; the flux used being that value corresponding to the product of primary turns and maximum instantaneous value of primary current for the particular brand of iron used, and is practically limited by saturation. This open circuit voltage for small transformers at ordinary frequencies may be less than 100 volts, and will scarcely exceed 1000 volts in the largest size. Apart from the building up of the secondary voltage, transformers should never be operated open circuited; since the iron losses, at the high density obtaining under this condition, cause serious heating, and the reactance of the primary in series with the line is objectionable.

PATENTS*

PART I

By ALBERT G. DAVIS

The following paper is designed to give some idea of the general object and nature of a patent. It is only a rough outline of general information, and is not to enable the reader to dispense with the services of a lawyer in any specific case.

I shall not consider copyrights, trade marks, labels, nor design patents; but patents for inventions—what we call mechanical patents.

The patent system is the outgrowth of a very odious system of monopolies, which were formally granted by the English Crown in the form of an open letter—from which comes our expression "Letters Patent." This was an open letter under the seal of the Crown, conferring the exclusive right to practice some business in the Realm. These monopolies became particularly objectionable during the reign of Queen Elizabeth, and not long after her reign they were abolished. A statute of James I contained a provision against monopolies being granted excepting to those who introduced new manufactures into the Realm, and this theory still survives in England in the patent of importation, or "communication."

In this country the patent law is based on a clause of the Constitution of the United States which gives Congress the right to grant to inventors, for limited periods of time, the exclusive right to enjoy the fruits of their inventions. A patent, therefore, is a Federal thing, that is, a thing of the Federal Government and not of the States. It is a grant of the exclusive right to make, use, and sell a certain invention for a certain period of time. An infringement consists in the making, using, or selling of the thing concerning which the grant was made, by some other person without authority. Patents are granted by the Government of the United States, under the seal of the Patent Office, and, of course, in accordance with the Statutes of the United States, and the Patent Law is a Statute Law. A patent is a creature of these statutes, and can only be considered with reference to them.

In this country a patent of the kind we are considering runs for seventeen years from the date of issue, not from the date of filing the application.

The following paragraph is Section 4886 of the Revised Statutes of the United States, as now amended. It is the fundamental basis of our patent law, and is worthy of careful reading, as every word means something.

> "Any person who has invented or discovered any new and useful art, machine, manufacture, or composition of matter, or any new and useful improvements thereof, not known or used by others in this country, before his invention or discovery thereof, and not patented or described in any printed publication in this or any foreign country, before his invention or discovery thereof, or more than two years prior to his application, and not in public use or on sale in this country for more than two years prior to his application, unless the same is proved to have been abandoned, may, upon payment of the fees required by law, and other due proceedings had, obtain a patent therefor."

As I have said, every word in this statute means something. Considering the separate phrases, we have, first:—"*Any person who has invented or discovered.*" This means that the application must be made by the inventor; no one else can make it; otherwise it is void. If two persons jointly invent, and one files a sole application, or if two file a joint application on an invention made by one of them, no valid patent can issue on that application. So the person who furnishes the money, or a mere assignee, cannot make the application—it must be made by the inventor.

Next in the statute are the words:—"*Any new and useful.*" Of course a thing must be new, for this is the fundamental idea of a patent. (We will go a little more into detail regarding this later.)

If a thing is not "useful," no patent should be granted, but on the other hand, a small degree of utility will support a patent. If a thing is really harmful, the patent is void. For example, a device for perpetrating fraud on the public would be void. There was a case in Connecticut of a patent on a process for producing tobacco in imitation of certain high grade Cuban tobacco. It was found at one time, that in a certain district in Cuba, there was a parasite or fly, which, by biting the leaves of the tobacco plant, caused little white spots to appear; and the public got into the habit of looking for these spots and recognizing them as the mark of the tobacco of this particular district. This man in Connecticut conceived the idea of going out in his tobacco fields and spraying a certain solution on the leaves, and thus reproducing these white spots. He got a patent on this, though with considerable difficulty, as the Patent Office held that it was a fraudulent thing. He stated, however, that this invention made the cigars more free-burning, and on that ground a patent was granted. He prospered in this business for some time, until some other man decided that he would try it also. This brought up litigation, and the judge without hesitation held the patent invalid, resting his decision on the grounds of lack of utility. He said that there was no proof that the cigars really were more free-burning, though he seemed inclined to rest his decision on the broader ground of the essentially fraudulent nature of the business.

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* Lecture delivered before the Schenectady Section A.I.E.E.

What constitutes novelty? "*Not known or used by others in this country before his invention or discovery.*" If used in a foreign country, it does not affect an American patent, unless it can be shown that it is an idea brought home by the inventor, in which case the patent is void. If a man goes abroad and seeing something over there that seems to him meritorious, comes home and patents it, obviously he has not invented it. If, however, a man in this country invents a thing in good faith, the fact that it was *used* abroad is no bar to the patent, provided the thing was not "*patented or described in any printed publication in this or any foreign country, before his invention or discovery thereof.*" This relates to the date of his invention and not to the date of his patent. To grant to a man a patent on a thing that had been described in a printed publication before his discovery of it would be bad practice, because he might have read that publication; and in any event it would not be new, the world would be in possession of the invention. But if he had invented it in good faith before this publication was issued, he could file his application in this country within two years of that publication; otherwise it would be void.

Referring again to the statute we find the phrase:—"*Not in public use or on sale in this country for more than two years prior to his application.*" This means that a man cannot make an invention and allow his device to go into use or be sold to the public for an indefinite period, and then obtain a patent; he must file his application within two years from the time such public use begins. The question is, what constitutes public use, and this question is a very difficult one. For example, in the case where a pavement had been laid for six years on a toll road near Boston, it was held not to be in public use. The reason for this decision was that the pavement was held to be experimental, having been put down to determine whether it was serviceable. It was placed in front of a toll-gate, where the horses had to stop and start, and where the work on the pavement was the heaviest. Every few days the inventor would examine the pavement, would discuss it with the men, and find out every detail regarding it. He was held to have been experimenting, but that was an extreme case.

When a man has finished with his invention, when he is satisfied the thing is good, although capable of further improvements, then the use becomes public use under the statutes. Ordinarily, when he begins to derive profit, it constitutes public use.

Of course, an invention can be abandoned, as any other right and privilege can be abandoned. The right to own a piece of real estate can be abandoned; as is the case when a man allows the public to walk over a part of his land for a sufficient number of years; for there then accrues to the public the right of way over this particular lot of land, and thus to this extent it is an abandonment of the right of the proprietor. In the same way, a man who has made an invention and obtained thereby a right to apply for a patent, may abandon that right; either definitely and formally, by publishing a statement that he has made an invention and is not going to take a patent; or indefinitely and informally, by simply allowing it to run long enough to result in abandonment.

If we look at an American patent, we find that it usually contains a drawing, always a specification, and always certain short paragraphs which we call claims. The drawings are merely illustrations, the specification is the description, and the claim is the soul of the patent. The patent is in the nature of a contract—that is the modern view of it. The Government says to the individual: You have made an invention; you may, if you wish, keep that invention secret; you may use that invention as a secret process, and hand it down to your descendants if you can keep it secret; but if you come to us and tell us about this, explain it to us so that we can use it, then, as a reward for that, we will give you the exclusive privilege of the use of it for a term of seventeen years. The inventor must tell all he knows about it; if he deliberately holds back one thing vital, the patent is void.

In this matter of patents for inventions there is great diversity in the practice of the different countries. Obviously, a man ought to get the monopoly of whatever new patentable thing he has invented, but the practical question comes up as to just how to ascertain what that is. It should be well and sharply defined, but a careless or incompetent patent attorney should not be able to take any right from the inventor.

Latin nations follow the French system, which is exceedingly simple—a man files a description of an invention in the French patent office, and that is all there is to it. He can file the description of anything, and they will take it and grant a patent on it, and he can enforce that patent against anyone who uses any new or patentable thing found in the specification; but it is exceedingly difficult practically to find out what a French patent covers, on account of the absence of what we call the claims, and that is the difficulty with the French system.

The German system is something like the American; a man is required to claim what hc has invented. He specifies in a form of words the particular thing he has invented; but the construction of the claim is so different, the phraseology is so different, that we Americans, as a rule, cannot understand the German practice.

The Japanese system is intermediate between the German and American—it is not yet settled which way they are going. As far as I can see, the tendency is toward the German practice.

In this country we have another system, which is a logical antithesis of that of the French. Here a man with an invention gives a description of some new thing, but he must do more than this; he must select and define certain things and say: "these are mine." We call these claims, and the claim as I have said, is the soul of a patent. In a sewing machine, for example, a claim reads: "The combination of a wheel, a treadle a shuttle," etc. Now this means that this man thinks he is the first that has ever put a wheel, a treadle and a shuttle in a sewing machine, and if this is the case, no one else can do this without infringing. Broadly and roughly speaking, a claim is a combination, and a thing does not infringe that claim unless it contains every one of those things, every "element" of the combination. The mere fact that it contains more things will not prevent it from being an infringement. We put as little into a claim as we can. For if a certain combination is new and is made up of three elements, and we put in four, anybody can use the three elements providing he does not put in the fourth one; so we have given away some of our clients' rights to the public. Obviously the patentee must sharply define his claim. He often does it badly; he is often advised by poor attorneys, and is often ignorant of the real invention. It is exceedingly rare in ordinary practice for a man to know just what he has invented. An ordinary man says, "here is my invention," and it is a matter for cross-examination to find out what really belongs to him. Even the best of attorneys frequently fail to see the real gist of the invention and claim it more narrowly than they should.

Many will remember when the Tesla patents were patents on detail improvements on electric motors; and ten years later they were foundation patents at the basis of a great art. That means, an art has grown up under those patents. So it is hard to say which patents are narrow and which are broad.

A man can obtain a patent on anything that is new, whether he has a right to use it or not, provided it fulfills the statutory requirements. If I invent a certain thing and patent it, and some one else makes an improvement tomorrow, he can patent his improvement, but cannot use my patent. The mere fact that the patent office has granted him a patent does not mean that he has a right to use that thing, but merely that he has the right to keep other people from using it. A patent grants the *exclusive* right to make, use and sell an invention; it *excludes* others from the use of a certain thing. It is on that point that some interesting State and Federal decisions have been made.

There are a number of cases where a man has made an invention the use of which was prosecuted as a criminal act in a state where it was against the law, the defendant maintaining that the patent was granted under the federal laws and statutes and therefore took precedence over state laws. Take as an example the case of a man in the state of Maine making and selling whiskey made by the use of a patent still, and defending himself by saying: "This is my patent, in which the Government granted me the right to make, use and sell this invention; and I do not care for your local laws which say that it is wrong to distill whiskey." The courts would hold that to be no defense, and the true reason for this is that the patent did not grant to this man a right to do anything, but simply the right to prevent others from doing something. It is no protection for him to say that he is working under the laws of the United States. The only thing he can do is to prevent other people from distilling whiskey with that particular still.

Take as an illustration the automobile tire or bicycle tire. There was once a time when somebody had the conception of running a wheel on air enclosed in a surrounding tube. That thing was or might have been patented, and there is no reason why the man should not have had a patent as broad as the idea of the pneumatic tire. Suppose he had taken out that patent, showing the old hose-pipe bicycle tire. Then suppose that in time it was found that it was difficult to repair a tire of that nature, and some one conceived the idea that the tube itself need not be circular and continuous, but could be locked into the rim at each side; and that it need not be air-tight provided there is an air-tight tube inside, thus making the double-tube tire. Now he could patent that, of course. Then perhaps somebody wanted a means for taking off the tire more quickly, and got the idea of a quickly detachable tire, and so on; a dozen or a hundred inventions, culminating in some good automobile tire. Now the second man cannot make his tire unless the first man lets him. The man who conceived the idea of the double tube tire must use the invention of the first man, and so on. Of course, the first man's patent will expire, and then the second will go ahead.

(*To be continued*)

THE COST OF COPPER

By George L. Walker

Author Walker's Copper Letters, Editor Boston Commercial

The cost of producing copper depends chiefly upon the richness of the ore and the size of the ore deposit; but much depends also on the character of the mineralization, and minerals which are associated with the copper. Copper ores which do not yield readily to known methods of reduction are called refractory. The most refractory ores are those in which the copper occurs as oxides and carbonates in a highly silicious gangue; and those ores in which the copper occurs in any of its various mineral forms associated with zinc, nickel, antimony or arsenic are also difficult to smelt and refine.

The theory that there are some considerable deposits of high grade ores which cannot be smelted or treated profitably, and the belief that large masses of native copper exist which cannot be cut up, are both unfounded. All of the large masses of copper ever found were cut up and marketed very profitably. Modern metallurgists can treat any ore in existence at a good profit, provided it is rich and exists in sufficient quantities to warrant the construction of large plants.

As a result of my personal inspection of practically all the producing copper mines in the United States and Canada and the largest one in Mexico, I have come to believe that necessity helps to develop an economical management and attain low production costs. The management of a mine in which there is an abundance of rich ore is always prone to overlook many of the small opportunities for economy of operation; but the manager who is forced to continue development work tirelessly in order to keep a mill running on a very poor grade of ore, and from it win profits, is pretty sure to give careful attention to every known method of economy and use every one of them to its best possible advantage. Human nature asserts itself in mining as in all other pursuits, and the traditional relationship between necessity and invention is never severed.

In copper mining the best results are practically always obtained from working very large bodies of low grade ore. To illustrate: in the Cobalt silver district it costs $60.00 to $150.00 per ton to mine ore from veins which average three or four inches wide;

while in the British Columbia copper camp ore is extracted from a lode 300 feet thick, trammed half a mile and loaded on railroad cars at a cost of $1.02 per ton.

Of course it is not practical to set up heavy modern mechanical equipment, hoists, electric tramways, etc., to mine a small ore body. The narrower the vein and the more "bunchy" the deposit, the greater relatively is the amount of dead work which must be done to mine a given tonnage of ore; hence the cost per ton increases with the narrowness of the vein.

Those who know little or nothing of copper mining will be interested in a brief summary of the methods by which the red metal is won from Mother Earth in different mining districts.

At Lake Superior native (pure) copper occurs disseminated, chiefly in small particles, throughout porous beds or lodes of hard trap rock, called amygdaloid. About 120,000,000 pounds is produced there annually from this rock which yields an average of about 18 pounds of fine copper to the ton, giving the rock a gross value of only $2.50 on a 13-cent copper market. The total average cost of handling this rock, however, is only about $1.80, which means a production cost of 10 cents per pound. This does not include the Calumet & Hecla which produces from 85,000,000 to 90,000,000 pounds annually from a conglomerate rock which yields about 40 pounds to the ton at a cost of about 9 cents per pound. The Tamarack and Franklin produce 15,000,000 to 20,000,000 pounds annually from lower grade conglomerate rock at a higher cost.

At a cost of 15 to 25 cents per ton, Lake Superior rock is milled and concentrated, 40 to 80 tons into one, and the mineral, or native copper, is refined by a simple smelting or melting process and put into the various shapes ready to be drawn into wire or rolled into sheets. It commands a higher price in the markets of the world than any other copper. Natural conditions are such that the simplest processes in use anywhere in the world can be employed.

At Butte, Montana, the leading copper producing district of the world, the copper ores, chiefly chalcocite and enargite, occur in big fissure veins in a granite formation. The disposition of the wall rock to cave, necessitating the use of a great deal of strong timber and the refilling of stopes, makes the mining cost high.

The ores are transported a considerable distance, the lower grade concentrated in big mills and the higher grade smelted direct. A portion of the ores have to be roasted to expel the excess sulphur before smelting. The arsenic is precipitated to prevent injury to vegetation and, incidentally, it is refined and sold, yielding a fair manufacturing profit.

The matte, the first smelter product, is converted into buillion, about 99 per cent. fine. Then the copper is shipped to the Atlantic seaboard and refined electrolytically, a combined process of chemical and electric treatment, the result of which is a chemically pure copper.

Butte ores yield an average of 65 pounds of copper to the ton; but operating expenses exceed $8.00 per ton. From $1.00 to $1.50 in silver and gold is recovered, however, which keeps the cost of copper down around 10 cents.

There are only a few copper concentrating mills at work in Arizona, two each at Clifton and Morenci, and one at Globe; but the greater portion of all the Arizona ores are smelted in bulk as they come from the mines.

Bisbee is the highest grade copper district in the world. All the ore mined and treated there yields an average of 7 or 8 per cent. copper. The managers of the Bisbee mines and smelters, as a result, do not watch the cents but the dollars, and even these are not looked after so carefully but what another one could be saved per ton of ore treated, provided such a saving was really necessary. It is not—the mines of Bisbee pour out a golden river of profits year after year.

In the boundary district of British Columbia what appears to have been originally a gigantic deposit of volcanic ash is being smelted direct and is yielding copper at as low a cost as 8½ cents per pound. It is self-fluxing, containing all the lime and iron necessary to carry the ore through the furnace and making possible a very low smelting cost. Only about 25 pounds of copper, or about 1¼ per cent. is recovered; but the ore also yields about $1.40 per ton in gold and silver. Mining is done at an exceedingly low cost, also, the total operating expenses figuring only about $3.00 per ton.

At Ducktown, Tenn., ores yielding 32 to 33 pounds of copper, and carrying no precious metal values, are being mined from very wide veins and handled so economically that the copper is produced at a cost of about 9 cents, the direct blast furnace smelting system being employed.

Of tremendous interest at the present time are the plans being worked out on a gigantic scale for the treatment of the large deposits of secondarily enriched porphyry at Bingham, Utah, and Ely, Nevada. At the first point one company is now treating over 5,000 tons of ore daily at a gross cost from the ground to the copper market of $2.10 per ton of ore. This ore contains less than 2 per cent. copper and the portion now being treated yields only 26 pounds to the ton. At this rate the cost is only 8 cents per pound of copper. There is reason to believe that these big porphyry deposits will be a tremendous factor in the copper metal market in the future.

In discussing copper costs I have included not only the expenses at the mine but those of management as well, so that my figures cover the cost of delivering refined copper to consumers, all expenses paid. Where ores contain gold and silver in addition to copper, the cost of the precious metals is not figured. It is assumed that they help pay the expenses of mining and treating the ores and thus reduce the cost of copper proportionately; copper, not gold and silver, being the metal sought.

The average cost of producing the world's output of refined copper during the past 25 years probably has been slightly less than 10 cents per pound. The average selling price has been about 13½ cents per pound, resulting in a very substantial profit for an industry of such magnitude. As the world's copper output in 1907 probably cost about 10½ cents, and has been sold at an average of about 17½ cents, there was a net profit of 7 cents per pound, or a total profit of over $100,000,000 on the product of the world's copper mines, which aggregated about 1,550,000,000 pounds. If the price of copper averages less than 14 cents per pound during the present year, production probably will not exceed 1,350,000,000 pounds, and the aggregate profit at 13½ cents will be about $50,000,000.

In view of the fact that there are a great many mines in which the copper costs from 11 to 13 cents per pound, there may be some authorities who will dispute my estimate of 10½ cents as the average production cost last year. With one or two exceptions, however, all of the world's largest copper mines make their product at a comparatively low cost. About 30 per cent. of the world's 1907 output was produced by nine mines; Anaconda, Boston & Montana, Copper Queen, Rio Tinto, Calumet & Hecla, Copper Range, Calumet & Arizona, North Butte and United Verde. All of these, with the exception of Anaconda, produced their copper for 9 cents per pound or less; Anaconda's cost was probably 10, but possibly 10½ cents. Rio Tinto's cost probably did not exceed 7½ cents, Calumet & Arizona's 7½ cents, and Boston & Montana's 8½ cents.

There are a few moderately large producers, among which may be mentioned Greene Consolidated, the Mansfield of Germany, Arizona Copper and the Old Dominion, whose copper costs from 11 to 15 cents per pound. But the aggregate production of these four companies is only equal to that of the Copper Queen and Calumet & Arizona combined, which are capable of making their copper at a cost of 7½ cents.

The cost of copper has very little to do with its market price. During the civil war, from 1861 until 1866, the price of copper did not decline below 17½ cents, and it rose in July, 1864, as high as 55 cents. At that time miners were scarce and wages high; and uncertainty as to the future of the country had prevented a continuation of expansion and progress along general business lines, and in the copper producing world particularly. When business began to revive there was a scarcity of copper, and a sharp advance in price naturally followed.

The lowest price ever recorded for copper was 9 cents per pound. This quotation was made in January, 1894, and was the result of the halt in general business, due to the Bryan silver panic. The lowest price the metal touched at the time of the failure of the Secretan Syndicate, in 1885, was 9¾ cents.

While there have been most remarkable strides in the application of mechanical contrivances and of steam and electric power to copper mining, milling and smelting within a quarter of a century, the economies thus achieved have been very nearly counterbalanced by the advance in the wages of labor. I mention labor alone, but I wish it understood that the mining companies pay for labor not only in wages at the works, but in the higher prices of steel, coal, machinery and practically all supplies and equipment.

The high development of mechanical, mining and concentrating devices has made it possible to treat a very much lower grade of ore than could be handled profitably 20 years ago. It therefore has been productive of the custom of mining the lean ore with the rich, thus greatly increasing the ore tonnage handled daily and reducing the general average grade of ore treated in each of the several districts and by every big mine.

The managements of the big established mines of Butte, Lake Superior and other districts are not striving to reduce the average cost per pound of the copper produced by their companies. They are interested rather in reducing operating costs in every department, that by so doing they may be able to increase the available tonnage of ore in the mines. To illustrate, suppose that only those portions of a company's ore deposits which assay 3 per cent. or more can be mined and treated so as to yield copper at a cost of 10 cents. If the manager succeeds in reducing the average cost of handling a ton of ore by from $1.00 to $3.00, he will then be able to mine and treat all the ore in the deposit which contains more than 2 per cent., and still produce it at a cost of 10 cents. By doing this the total amount of ore available may be increased 50 per cent., and thus may add millions of dollars to the value of the property. For instance, 3,000,000 tons of ore averaging 2½ per cent. unavailable when operating costs were $6.00 per ton, on an operating cost of $4.00 would yield up its copper at a cost of 10 cents, and would be worth, with copper at 13 cents, $1.25 per ton net, or $3,750,000, as the ore would return this amount in profits.

The assertion often heard that there is copper enough along Copper River in Alaska to supply the world for a thousand years, should not be taken too literally. There is enough copper in the Lake Superior district, at Butte and in Arizona to flood the markets and close down all the other copper mines in the world, provided this copper could all be produced immediately at a very low cost. It is probable that 75 per cent., and possibly 90 per cent. of all the copper in and adjacent to the districts named is so widely disseminated through the country rock as to make its recovery at a profit by any known method impossible. You must build mills or smelters or both before you can produce copper, and after they are finished there is a limit to their capacity.

Speaking of a thousand years, a considerable portion of this time will be required to develop, equip and man the copper deposits of Alaska and make them ready for production on any considerable scale. Alaska has the disadvantage of low grade ores and isolation from transportation and supply centers, and the only way to get labor there is to import it and then make living conditions sufficiently attractive to keep it there—by no means an easy undertaking.

It requires from three to ten years to develop and equip a large copper mining enterprise. Therefore, every time the world's consumptive demand has a sudden and unexpected increase, the price of copper must go soaring into the clouds. On the other hand, whenever there is a sudden contraction in the volume of the business of several countries at the same time, the price of copper has a severe decline.

It is not necessary to tell the readers of an electrical magazine that the future of the copper producing business is assured. The electrical age, upon which we are now entering, of course means an age of copper. As the development of the steam railroad was predicated upon a profitable iron and coal mining business, so must electrical progress make a market for a steadily growing production of copper.

The world's great copper deposits are in the United States. Though this country is young, its mines located far inland, and its wage scale higher than any other, it produces about 60 per cent. of the world's copper output. Copper has the advantage of a world-wide market, always selling on a given day at the same price in Tokio, London, New York and San Francisco. Copper can be shipped half way around the world for 6 per cent. of its value, while it would cost 150 to 200 per cent. of the value of pig iron to transport it a like distance. When the industries of one country are depressed, therefore, a market for copper can usually be found in others. During the past six months, for instance, much more than the normal proportion of the production of this country's mines has been sold in Europe, domestic consumption having declined 50 to 60 per cent.

THE ELEMENTS OF STEAM LOCOMOTIVE DESIGN*

By C. J. Mellin

The design of a locomotive is based on the conditions under which it is to work and the kind of service required. These factors govern the type and proportions of the engine if left to the builder for decision; the type, however, is in many instances a choice of the purchaser. In either case, the first consideration is the allowable wheel pressure on the rail, and by this is determined the weight on the driving wheels. The maximum curvature of the road limits the length of the rigid driving wheel base, and, in the best cases, it is not advisable to make this over 16 or 17 feet, and then only for slow-going freight engines. This generally limits the number of driving wheels to four pairs for freight and three pairs for passenger engines. It is better to couple as few wheels together as possible, and therefore three pairs of coupled drivers are often used for freight, and generally two for passenger service. So far as the driving wheel arrangement goes, this would only make four types of road engines; but as all road engines must, for the sake of safety, have a guiding truck, it is generally considered that a two-wheel or "pony" truck, is the most suitable for freight engines, partly because it can be held to the track with less dead weight, and partly because it adds the least to the already long total wheel base of the engine. The four-wheeled truck is mostly used in passenger service.

There are further to be considered fast freight, and mixed freight and passenger service, in which both types of trucks are used, and to meet these varying conditions, several types of engines are brought into existence.

These various types are distinguished from each other by names and figures, depending on the wheel arrangement. For the ordinary locomotives, these figures represent the grouping of the wheels, where the first figure signifies the number of wheels on the first truck; the second, the number of drivers; and the third, the number of wheels in the trailing truck.

We have thus the light passenger or eight-wheeled engine, with a four-wheel truck and four coupled drivers, which is classified as 4-4-0, the last figure indicating that there are no trailing wheels; medium sized passenger engines, or Atlantic type 4-4-2; heavy passenger engines, or Pacific type 4-6-2; and the ten-wheel type 4-6-0. The latter, as well as the Mogul engine 2-6-0, and the Prairie type 2-6-2, are also very suitable for mixed or fast freight service. For regular freight service, the Consolidation class 2-8-0 has practically become the standard, and for heavy freight the Articulated class 0-66-0 is rapidly looming up as another advance toward meeting the constantly growing demand for increased power units.

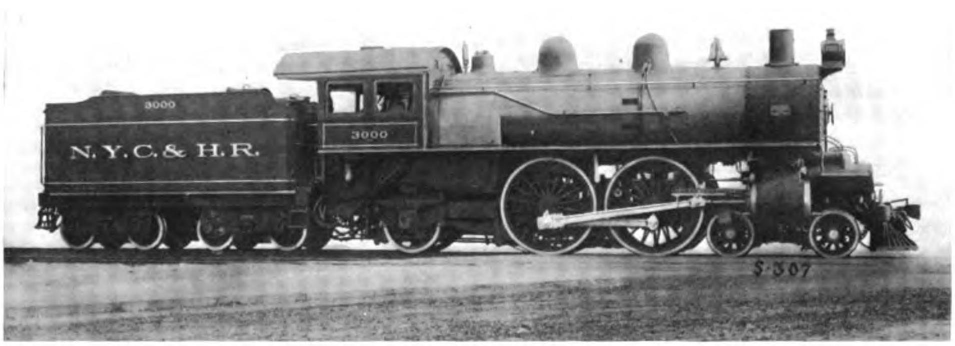

Fig. 1. Atlantic Type of Passenger Engine. Weight of Engine 200,000 lbs.; Weight of Tender 122,000 lbs. Tractive Effort, 23,500 lbs.

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* Lecture delivered before Schenectady Section A.I.E.E.

For switching service, it is considered that no truck is needed for guiding purposes, and the slow and intermittent runs, and consequently the smaller weight of the boiler, favors the adoption of only coupled wheels and a short wheel base, which is of great advantage in view of the numerous and sharp curves in yards and around freight houses. The 0-6-0 type has practically obtained the entire possession of this field, and only in a few instances has it admitted the 0-8-0 type as a special assistant.

This comprises practically all of the general types of engines for ordinary railway service, and we shall find after careful investigation, that each of the above types meets conditions on the road where it is more suitable than any of the other types.

The large demand of speed and power for passenger service brought into existence the Atlantic and Pacific types, superseding the eight and ten wheel engines with larger wheels, larger cylinders, and consequently larger boilers. These enlargements necessarily increased the weight of the engines beyond the allowable rail load, and the spread of the firebox for obtaining the required grate area necessitated the introduction of a pair of trailing wheels under the overhanging firebox.

As previously stated, the road and service conditions determine the size and type of the engine, which means, in the first case, the allowable weight per driving wheels on the rail; secondly, the required hauling capacity; and thirdly, the service speed (and maximum speed at a given weight of train if the engine is intended for passenger service). Maximum grade, condition of road bed, curves and bridges are all factors that must be considered in order to produce the most servicable engine. These conditions are often of so fluctuating a nature that only experience and good judgment can determine the most suitable type and the fundamental dimensions. Thus the type and the combined weight and diameter of the driving wheels are decided upon, and usually the total weight of the engine. Within these limitations the work of laying out the engine can be started. The required cylinder power is figured out on the basis of the tractive weight, which is only another designation for the weight of the driving wheels on the rail.

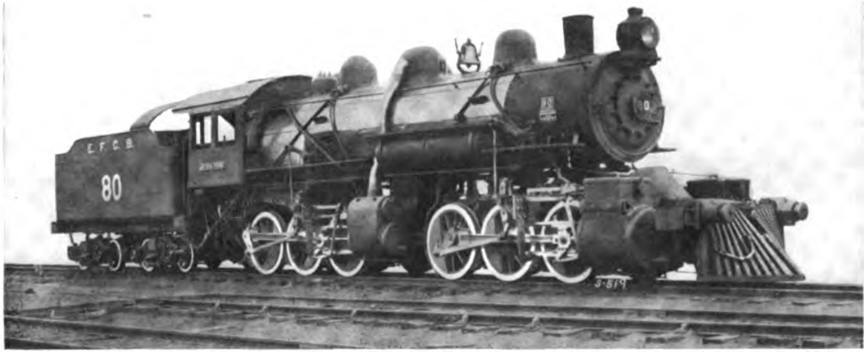


Fig. 2. Articulated Type of Freight Locomotive. Twelve Drivers. Weight of Engine 206,000 lbs.; Weight of Tender 90,000 lbs. Tractive Effort, 42,400 lbs.

The tractive power is usually figured out to be 22 to 23% of this weight, and is found by the following formula:

$$\frac{23W}{100} = \frac{CPd^2S}{D} = F \qquad (1)$$

where W = the weight exerted by the drivers on the rail;

C = a coefficient varying with the speed and cut off;

d = diameter of the cylinder;

S = stroke of the piston;

P = boiler pressure;

D = diameter of the drivers;

F = tractive power.

The boiler pressure is always predetermined, while the diameter of the drivers is in proportion to the required speed, and is made about equal, in inches, to the speed in miles per hour, at which the engine is expected to run. The stroke is selected so as to give the required maximum train speed with a moderate piston speed.

We have next to find the diameter of the cylinder, but this is dependent on the value of C at the maximum speed and cut-off. This value is expressed as a percentage of the boiler pressure, and when multiplied by the latter, gives the average cylinder pressure. The average pressure for a given cut-off may be found from formula 2 as follows:

$$P_1 = \frac{P\,(1 + \log_e n)}{n} - 15 \qquad (2)$$

where P_1 = the average pressure in the cylinder with n number of expansions. Since the engine is non-condensing, the atmospheric pressure (15 lbs.) must be subtracted. This formula gives us the result of a constant product of volume times pressure, whereas steam expands adiabatically; that is, the temperature falls with the pressure and causes a slight fall in the expansion curve.

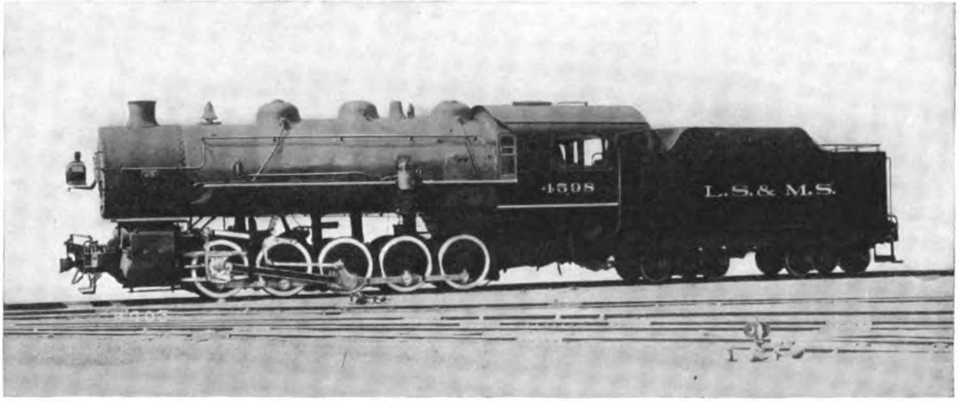


Fig. 3. "Hump" Type Freight Locomotive—Special. Weight of Engine 270,000 lbs.; Weight of Tender 149,600 lbs. Tractive Effort, 55,362 lbs.

We have further a "wire drawing" of the steam at high speeds, and back pressure to take into consideration; these modify the expression for formula 2 and make it uncertain, because of the uncertainty of the actual loss in pressure due to the higher velocities of the steam through the passages, and to cylinder condensation. In the ordinary engine the number of expansions are seldom over three, and at the maximum power this is only an extremely small fraction of the admission volume. Therefore, the generally accepted value of C is 85% of the boiler pressure, for a piston speed not exceeding 250 feet per minute and with a cut-off at 87% of the stroke; this gives the maximum tractive power of the engine, and is the regular rule for simple freight engines.

For high speed the value of C falls gradually, and will be about 30% at 1000 feet per minute piston speed.

It remains now to find the diameter of the cylinders, which is done by transposing formula 1 as follows:

$$d^2 = \frac{DF}{CPS}, \text{ or } d = \sqrt{\frac{DF}{CPS}} \qquad (3)$$

The train resistance must not, of course, exceed the pulling power of the engine, and the size of the train will be arranged accordingly. In many instances the weight of the train is put down as the fundamental requirement, and it is then necessary to find the resistance of the train, and from this side of the question determine the tractive power and number of driving wheels needed to handle this resistance.

It will be considered that for passenger service the weight of the train must always be limited to the tractive force obtained by employing three pairs of coupled wheels, because the long wheel base that an additional coupled pair of wheels necessitates is dangerous for high speed on curves. In freight service, however, a comparatively recent development has been introduced by subdividing the driving wheels into two groups of engines in a so-called articulated system, whereby practically any desired size of train can be handled, limited only by the strength of the draft gears. It is not improbable that this type will find its way into passenger service also, to meet exceptionally heavy road conditions.

The train resistance per ton weight due to rolling, is found to be $=\frac{V}{4}+2$, where V is the speed of the train in miles per hour.

Resistance due to grade = sin x, or sine of the angle of inclination, which is usually expressed in feet per mile. Calling the number of feet of inclination per mile M, we get the resistance per ton of train weight

$$=\frac{2000}{5280}M = 0.38M$$

The curve resistance is found to be about 0.5 lb. per degree of curvature per ton.

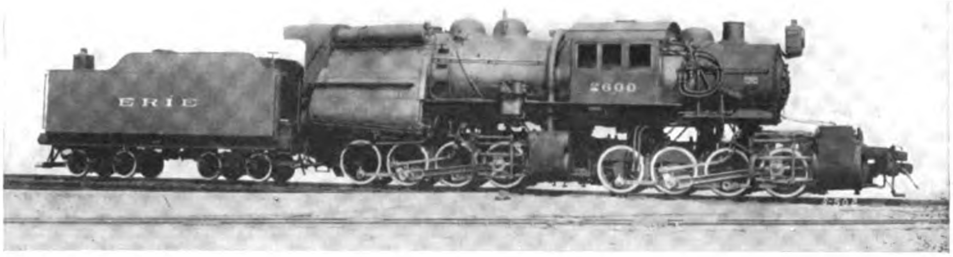


Fig. 4. The Latest Type of Articulated Freight Locomotive. Largest Engine Ever Built. Weight of Engine 410,000 lbs.; Weight of Tender 160,000 lbs. Tractive Effort 94,800 lbs.

The acceleration, including the revolving of wheels and axles with that of the weight of the train, figures up to be about $0.0126V^2$ per ton.

Adding to this the resistance of the engine, we get the following formula, which must be equal to F in formula 1, namely:

$$R=1.08\left(\frac{V}{4}+2+.38M+.5b+.0126V^2\right)T=F \qquad (4)$$

R being the resistance of the train, including the weight of the engine and tender; and being the opposite of the tractive power, it is also equal to F. The symbol b represents the number of degrees of the sharpest curve, and T the number of tons in total weight of train and engine, which, when F is given, will be

$$T=\frac{F}{1.08(\frac{V}{4}+2+.38M+.5b+.0126V^2)} \qquad (5)$$

The factor 1.08 represents the internal resistance in the engine.

For the resistance at uniform speed, the term $0.0126V^2$ representing the acceleration should be eliminated, since no further acceleration takes place, and consequently such resistance disappears.

The tractive power of compound engines is based on the low-pressure cylinder only, when working compound. In the following formula for compound working, d represents the diameter, of the low-pressure cylinder, while the coefficient C is a modification of formula 2, and for maximum power is equal to 0.54 when the cylinder ratio is 1:2½, as is usual in two cylinder or cross-compound engines. Where the ratio increases, as is the case in some designs of three and four cylinder engines, the value of C decreases.

When working the compound engine simple, with independent exhaust for the high-pressure cylinder, at will, and with properly reduced pressure for the low-pressure cylinder, the high-pressure cylinder is the base for the tractive power, as per formula 1, or:

$$F=\frac{CPd^2S}{D} \text{ (working simple)} \qquad (6)$$

where d = diameter of high-pressure cylinder and C = 0.85:

For working compound:

$$F=\frac{CPd^2S}{2D} \tag{7}$$

where d = diameter of low-pressure cylinder, and $C=0.54$.

For three and four cylinder compounds, where the cylinder ratios are 1:3, and where two low-pressure cylinders are used, we get, when working compound:

$$F=\frac{CPd^2S}{D} \tag{8}$$

where d = diameter of low-pressure cylinder and $= C$ 0.50. If provided with an intercepting valve for simple working, 20% increase in tractive power is obtainable.

For four-cylinder articulated engines, the same formula (7) holds good for working compound, but as the cylinder ratio is about 1:2½, the value of $C=0.54$.

In working the articulated engine simple we get:

$$F=2\left(\frac{CPd^2S}{D}\right) \tag{9}$$

where d = diameter of high-pressure cylinder, and $C=0.85$.

For triple expansion engine, with two low-pressure cylinders, formula 7 is used by substituting 0.40 as the value of C; but this takes us somewhat into the future, and we will leave off here for the present, merely pointing towards what we still have undeveloped ahead of us.

Since we have found the cylinder diameters and the stroke of the piston, we will proceed to determine the heating surface and grate area, which are two of the most important factors in a successful locomotive.

There are two different methods employed for determining these factors; one being based on the maximum horse-power that the engine must develop, while the other is to proportion them on the volume of the cylinders. A third method; namely, to base the amount of steam used on the cut-off pressure when the greatest horse-power is being developed, is probably as good as any, when the actual cut-off pressure can be obtained in advance; but as that usually has to be estimated, it would be difficult to arrive at any uniformity. As this is also to a great extent the case with the first method, the second is very generally adopted and found to give satisfactory results.

This method is to make the heating surface in square feet, not less than 450 times the volume of one of the cylinders in cubic feet, for passenger engines, and 400 times this volume for freight engines; it is desirable to make it greater when the weight of the engine and other circumstances will admit. The grate area should be about $\frac{1}{70}$ of this amount.

A selection of a graphic representation pertaining to the balancing of and the distribution of weights of Articulated engines is shown in Fig. 5, an explanation of which is as follows:

The Articulated type of engine consists of two systems, of lateral flexibility in their relation to each other, of which the front group of wheels, with frames, cross-ties and low-pressure cylinders, forms one system; and the rear group, with frames, cross-ties, high-pressure cylinders, boiler, cab and fittings, forms the other. The location of the small balls in the cut represent the longitudinal center of gravity of the respective systems, and the arrows under the wheel groups, the supporting centers.

It will be noticed that the center of gravity in both cases falls ahead of the supporting centers, and that the rear system with the boiler, etc., is considerably heavier than the front system. One-half of the difference of the weights must therefore be carried by the front engine in such a way that it balances the weight of the latter over its supporting point. The momentum curve of the front engine is transferred to the rear of its supporting center, and the momemtum curve of the rear system is extended until it intersects with the former. These curves are laid out with reference to the respective supporting centers, and the weight represented by their vertical height above a common base line.

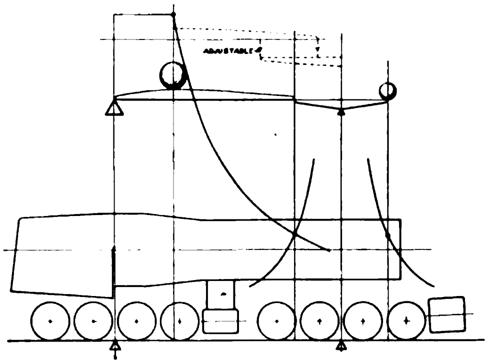


Fig. 5. Diagram Showing System of Weight Distribution of Locomotive shown in Fig. 4

We can now readily find the weight on the rail of each system, which, due to continuous equalization within itself, is concentrated in the middle of each wheel group, referred to above as supporting centers indicated by arrows. In order to obtain equal weight on both supporting centers or both groups of wheels, the center of gravity of each system must be thoroughly figured out and the various parts of the engine so placed that the desired location of the intersecting point is obtained. This intersecting point then becomes the vertical bearing point on the front engine where one-half the difference of the weights between the two systems must rest to bring the front engine in complete equilibrium over its own supporting center, and equal distribution throughout the entire engine takes place as illustrated by the lever system in the upper part of the figure.

This is the ideal condition, which, however, for ordinary service will produce too sensitive an engine. It is better to locate the actual bearing point in front of the virtual one and apply an adjustable hanger, or strut, as may be most convenient, in the rear of this, as indicated in the top of the figure, and thereby establish the desirable stability without disturbing its equalization.

INFLUENCE OF WAVE FORM OF E.M.F. ON CORE LOSS AND EXCITING CURRENT IN TRANSFORMERS

PART II

By L. T. Robinson and O. Holz

General Electric Standardizing Laboratory

The exciting current, which we will call I_t, is composed of two components, the energy current I_e, and the magnetizing current I_m.

The energy current is that component of the total exciting current which is in phase with the impressed electromotive force E, and is equal to the watts supplied to the core divided by the e.m.f. impressed; the $I\,R$ drop of voltage due to the exciting current being negligible

$$I_e = \frac{W}{E} \qquad (6)$$

The magnetizing current is that component of the total exciting current which is at right angles to the impressed e.m.f. E, and is therefore equal to

$$I_m = \sqrt{I_t^2 - I_e^2} \qquad (7)$$

The relation between the two currents I_e and I_m and the total current I_t can also be expressed as

$$I_e = \cos\theta \times I_t, \text{ and} \qquad (8)$$

$$I_m = \sin\theta \times I_t \qquad (9)$$

The currents are given in effective values, and θ is the equivalent angle of lag corresponding to sine waves.

It has already been shown that the hysteresis component of the core loss is inversely proportional to the 1.6 power of the form-factor of the e.m.f. wave; therefore the energy current is influenced by the form-factor of the wave, because the quantity W is made up of hysteresis and eddy components. Hence, the effect of the e.m.f. wave on I_e may be determined by separating I_e into its eddy and hysteresis components and correcting the hysteresis component alone for the form-factor of the wave; or we may write

$$I_e = \frac{W_h + W_e}{E} = \frac{W_h}{E} + \frac{W_e}{E}$$

where W_e is power consumed by eddy currents and W_h is the hysteresis loss on any wave b, differing from a sine wave a, and equal to W_h observed multiplied by

$$\left(\frac{1.11}{\text{form-factor of } b}\right)^{1.6}$$

Let us now consider in what way the correction for wave shape may be applied to the magnetizing current I_m.

The maximum magnetization caused by I_m depends not on the effective value of I_m but on its maximum value, and also upon the permeability of the core at the maximum magnetization.

Different magnetizing currents are computed from I_t by (7) or (9), which will give the effective values, as I_t will be observed on an ammeter, and hence its effective value only is known. The maximum value of I_m must be that which will give a density corresponding to the form-factor of the wave b on which the observations are made. The density is found from equation:

$$B_b = \frac{E \times 10^8}{4 \times A \times N \times \text{cycles} \times \text{form-factor}} \qquad (10)$$

where A is the cross section of the iron core and N is the number of convolutions in the winding used

$$\text{or} \qquad B_b = \frac{K}{\text{form-factor } b}$$

$$\text{and} \qquad B_a = \frac{K}{\text{form-factor } a} \qquad (11)$$

$$\therefore \qquad \frac{B_a}{B_b} = \frac{\text{form-factor } b}{\text{form-factor } a}$$

$$\text{and} \qquad B_a = \frac{\text{form-factor } b}{\text{form-factor } a} \times B_b$$

The form-factor a of sine wave is

$$\frac{\frac{1}{\sqrt{2}}}{\frac{2}{\pi}} = \frac{\pi}{2\sqrt{2}} = 1.11$$

from which we find B_a at sine wave.

Now, knowing both densities, that of test and that corresponding to sine wave, we find from the saturation curve of the transformer H_b corresponding to test wave b, and H_a corresponding to sine wave a.

As $\quad H = \frac{4\pi}{10} \times N \times I_m$ max., we have

$$\frac{H_a}{H_b} = \frac{I_m \text{ max. with e.m.f. wave } a}{I_m \text{ max. with e.m.f. } b} \qquad (12)$$

To simplify notation, it will be understood that I_{ma} is the magnetizing current with impressed e.m.f. of wave shape a, and the same with respect to I_{mb}.

Now, $\frac{I_m \text{ max.}}{I_m \text{ effective}}$ is called the amplitude factor, or I_m max. $= I_m$ effective $\times$ amplitude factor.

$$\therefore \frac{H_a}{H_b} = \frac{I_{ma} \text{ effective} \times \text{amplitude factor of } a}{I_{mb} \text{ effective} \times \text{amplitude factor of } b}$$

and I_{ma} effective $= \frac{\text{amplitude factor of } b}{\text{amplitude factor of } a}$

$$\times \frac{H_a}{H_b} \times I_{mb} \text{ effective.} \qquad (13)$$

Now assume, for the sake of simplicity, that a and b have the same amplitude factor; we have then

$$I_m, \text{ at sine wave of e.m.f.} = \frac{H_a}{H_b} \times I_m \text{ of test.} \qquad (14)$$

To find the magnetizing force at densities below the knee of the saturation curve, it is preferable, due to the steepness of the B and H curve, to divide B by μ, instead of reading H directly from the B and H curve, in which case

$$I_m, \text{ at sine wave} = \frac{B_a \times \mu_b}{B_b \times \mu_a} \times I_m \text{ at test.} \qquad (15)$$

Therefore, the process of finding the magnetizing current corresponding to a sine wave e.m.f. a, consists in finding B existing at test by means of the form-factor (equation 10) of the impressed e.m.f. wave b, and multiplying this B by the ratio of the form-factor of test wave to that of sine wave (1.11). We thus find B for the sine wave. From the B and H, or B and μ curve, we find the corresponding H's, and we multiply I_m, as found by (7), by the ratio of H corresponding to B at sine wave e.m.f. a, to H corresponding to B of test wave b.

The two components of the exciting current on sine wave of e.m.f. a are now known, and are added at right angles to give the total exciting current I_t; *i. e.:*

$$\sqrt{I_m^2 + I_e^2} = I_t$$

Now assume that the wave of e.m.f. b, on which the exciting current I_t was determined, has the same form-factor as that mentioned on page 237 (April REVIEW); namely, 1.25.

In a transformer of 20% eddy loss and 80% hysteresis loss, we found that the core loss on a sine wave would be 1.23 times that found by testing on wave b. Assume now that we found on this wave b, that

$I_t = 2.5$
$E = 100$
watts $= 100$
power factor $= 0.4$

Now from (6) we find e.m.f. current

$$I_e = \frac{100\ (W)}{100\ (E)} = 1, \text{ and from (7) we find} \qquad (7)$$

magnetizing current $I_m = \sqrt{2.5^2 - 1^2} = 2.29$. W becoming 23% greater on sine wave. Therefore, from (6) we get $I_e = 1.23$.

To correct I_m, assume that we had a density of 11100 B on the test wave b; then the density on sine wave will become

$$11100 \times \frac{1.25}{1.11} = 12500.$$

Again referring to the saturation curve, we find that

$$H \text{ at } 11100\ B = 4.3$$
$$H \text{ at } 12500\ B = 6.5$$

The magnetizing current found above; namely 2.29, is now multiplied by $\frac{6.5}{4.3}$ to obtain the new magnetizing current on sine wave *a*, and is equal to 3.46, and the total exciting current $= \sqrt{3.46^2 + 1.23^2} = 3.68$.

That is, the total exciting current has been increased 47%, and the power factor of the core loss has become 0.334.

As before stated, this approximate correction of exciting current is based on the assumption that the ratio of I_m max. to I_m effective, is the same with e.m.f. wave *a* as with wave *b*. Actually, this ratio, or amplitude factor, which is on a sine wave $\sqrt{2}$ or 1.414, increases with the density, which fact makes the results calculated as above only approximately correct. The amplitude factor of the exciting current can be found from an oscillogram of the test wave, and this factor corrected for eddy currents would give the amplitude factor of I_{mb}. But the amplitude factor of I_{ma} would still be unknown. This latter may be determined by plotting the current wave from the hysteresis loop of the iron, but accuracy of this degree will rarely be required.

The correction computed as above applies to cores of perfectly closed magnetic circuits. In open circuits, that is, in cores with an air gap, the combined permeability of iron and air is more constant, and the magnetizing current will be subject to less variation; but it will be difficult to make comparison for different wave shapes, as core loss and magnetizing current will be influenced by the leakage which will vary at different densities.

In transformers with very high tension primaries or secondaries, say 100,000 or more volts, the exciting current contains another component of appreciable magnitude; *viz.*, the condenser or capacity current which flows through the dielectric, solid and liquid. This capacity current is very sensitive to wave shape, and its effect must be considered in dealing with the subject. This can only be dealt with by analyzing the wave shape of e.m.f. into the fundamental and its harmonics, and from this analysis computing the capacity currents and their effects.

While the wave *a* was assumed to be a sine wave, and the wave *b* was taken as a pointed one, and therefore producing smaller maximum *B* at a given voltage, the same method and formulæ may be employed when dealing with a wave *b* having form-factor less than 1.11. In this case, the correction to sine wave values will produce smaller values instead of larger, as shown in the examples taken.

It is also evident that observations on any wave *b* may be corrected to any wave *a* not a sine wave in the same manner, and the results which will be obtained on any known wave may be predicted.

The examples given are not taken from tests, but were chosen arbitrarily, simply to illustrate the use of the formulæ. The results of some actual tests in which the corrections have been applied in the manner outlined will next be considered.

(To be continued)

TUNGSTEN ECONOMY DIFFUSER

By W. D'A. Ryan

The tungsten economy diffuser fills the demand for a large lighting unit, having approximately the same power as the enclosed arc lamp, and provides, in addition, a light of variable intensity, with a wide range of wattage adjustment without mechanical change.

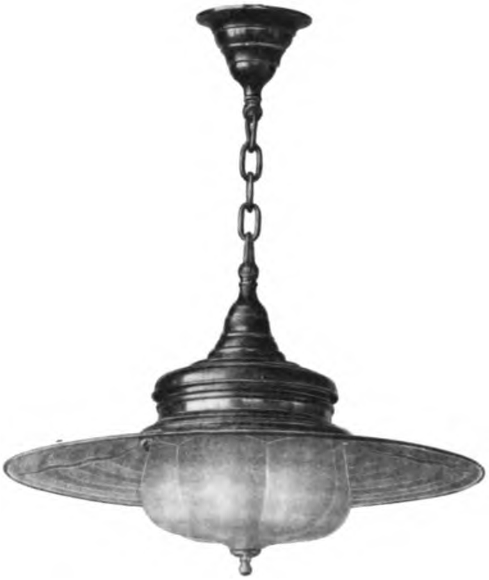


Fig. 1. 26 in. Tungsten Economy Diffuser for Store Lighting

By using various combinations of 40, 60 and 100 watt lamps, the cluster can be made to operate at 120, 180, 240, 300, 360, 420 and 480 watts, in the following combinations:

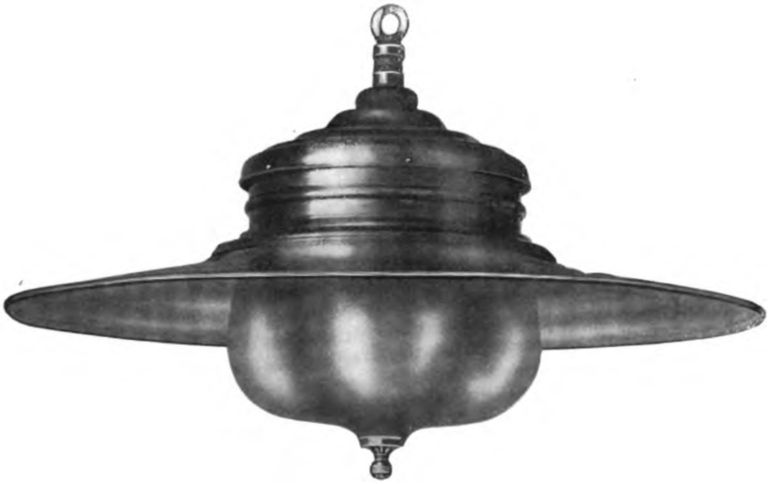


Fig. 2. 26 in. Tungsten Economy Diffuser for Mill Lighting

Single Circuit Combinations

3- 40 watt	120 watts
3- 60 watt	180 watts
3-100 watt	300 watts

Double Circuit Combinations

2 circuits of 3-40 watt lamps each,
120 and 240 watts
2 circuits of 3-60 watt lamps each,
180 and 360 watts

Double Circuit Triple Watt Combinations

3- 40 watt	120 watts	300 watts
3- 60 watt	180 watts	
3- 40 watt	120 watts	420 watts
3-100 watt	300 watts	
3- 60 watt	180 watts	480 watts
3-100 watt	300 watts	

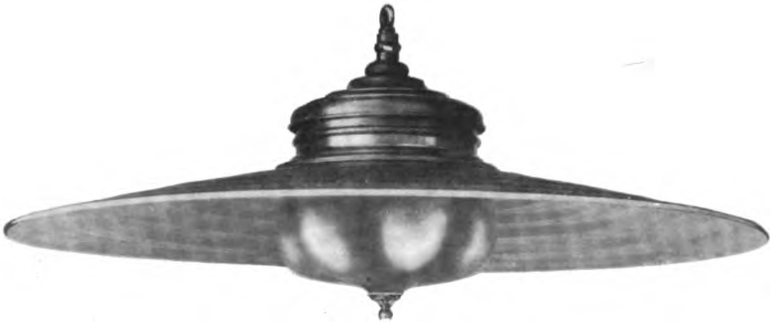


Fig. 3. 39 in. Tungsten Economy Diffuser for Mill Lighting

The triple combinations, such for example as the three 60 and the three 100 watt lamps, giving 180, 300 or 480 watts at will from a single switch, are of exceptional utilitarian and economical value.

Mechanical Construction

The diffuser is designed primarily to carry six tungsten lamps suspended in a vertical position. Very good results, however, can be obtained by the use of either tantalum or carbon filament incandescents. When the latter are used, the platform carrying the lamps can be readily lowered without taking the fixture apart. This adjustable feature makes the fixture universal for all types of incandescent lamps.

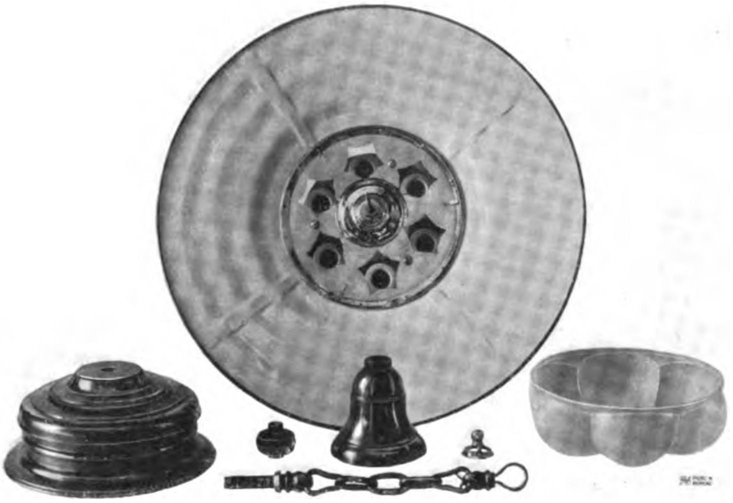


Fig. 4. Exploded View of 26 in. Diffuser

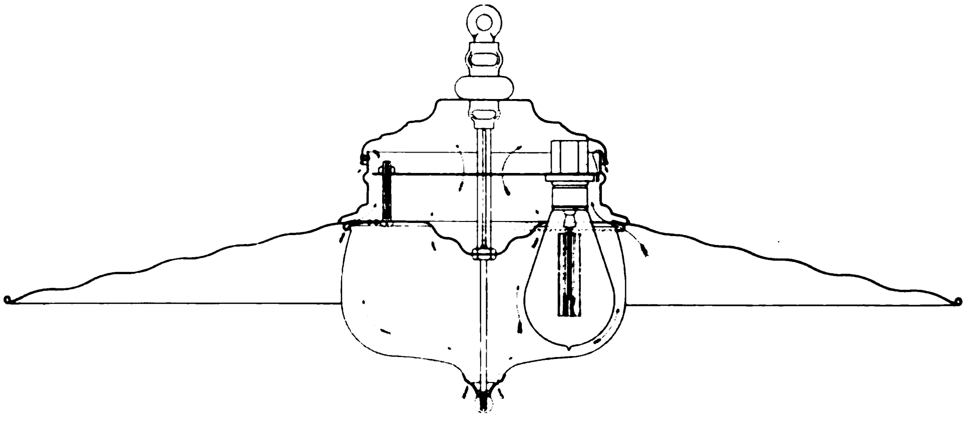


Fig. 5. Sectional Diagram Showing Passage of Air through Diffuser

For store lighting, the 26 in. diffuser is recommended, and for mill and factory work the 39 in. will be found more satisfactory, as it gives somewhat better distribution and diffusion, although it is not so attractive in appearance. We have found from experience that the 39 in. tungsten economy diffuser gives excellent results for mill lighting when equipped with three 100-watt tungsten lamps. This permits, for the same energy, somewhat closer spacing than arc lamps, which arrangement is particularly desirable on low-studded floors with over-head belting.

Finish

Fig. 1 shows the standard 26 in. cluster.

The diffuser is made of steel, coated with white porcelain enamel on the under side and black on the top. The supporting reflector is made of brass with nickel finish, and carries springs to compensate for expansion or variation in the size of the globes.

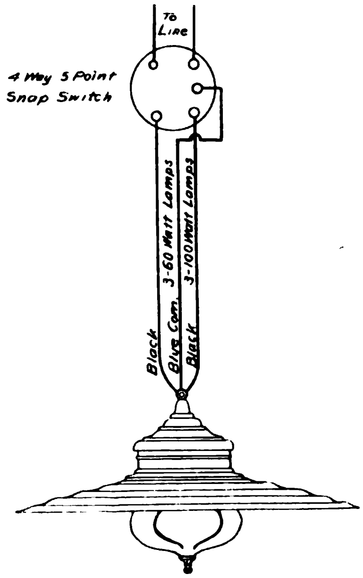


Fig. 6. Connections for Economy Diffuser

The casing is finished in streaked oxidized copper. When specially ordered, streaked oxidized silver or verde-antique can be supplied. The chain suspension and canopies are finished to correspond with the casing, and will be shipped only when called for in the requisition.

The 39 in. or mill type tungsten diffuser is identically the same as the 26 in., except that the diffuser is larger, and in place of being finished in porcelain enamel, it is coated with white zinc enamel. The 39 in, diffuser is shown in Fig. 3.

Shade

The shade is made of clear glass frosted on the inside, and is curved so as to take the general shape of the lamps. Placing the frosting on the inside of the shade gives a lower intrinsic brilliancy than is obtained by the same grade of frosting placed on the lamps, and does not reduce the life of the lamp.

The six-lobe shade is standard for all lamp combinations, and the curvature of the shade minimizes the spotted effect so apparent when part of the lamps are extinguished in a fixture having a spherical globe.

Ventilation

In order to prevent an excessive rise of temperature, the air is drawn into the bottom part of the reflector, passes around the bulbs of the lamps, and mixes with an upper ingress of air passing between the top of the shade and the reflector. This stream of air rises through the star-shaped openings in the central reflector and passes out through the ventilating ring in the casing.

Wiring

All fixtures are shipped wired for two circuits of three lamps each, one of the leads, which is common to both circuits, being blue, while the other two are black. When the customer does not wish to use the double or triple wattage combinations, the two black leads may be joined together, thereby making a single circuit.

When the double and triple combinations are required, we recommend the use of a five-point switch placed in one side of the line, as shown in Fig. 6.

When the diffuser is equipped with three 60 and three 100-watt lamps, the first point on the switch will turn on the three 60-watt lamps (180 watts); the second point will extinguish the "sixties" and turn on three 100-watt lamps (300 watts); and the third point will combine both groups, taking 480 watts. In all cases the fixture should be operated with either three or six lamps, as any other number will cause a distortion in the distribution of the light, and will destroy the symmetrical appearance of the fixture when lighted.

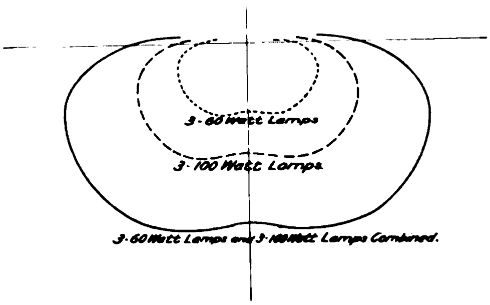


Fig. 7. Economy Photometric Curves, Showing Relative Illumination for the Different Combinations

TUNGSTEN LAMPS

By A. D. Page

Manager Incandescent Lamp Sales, General Electric Company

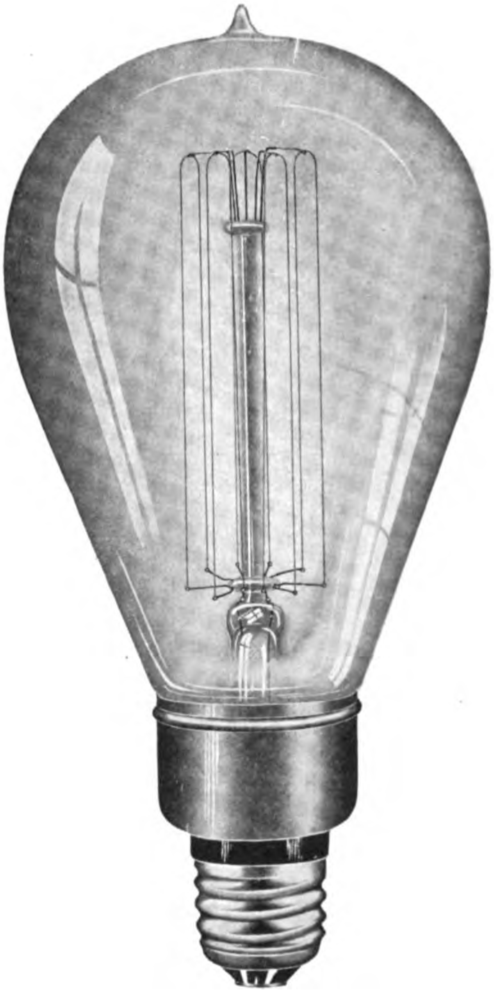
The General Electric Company has met with very gratifying success in the introduction of the tungsten lamp, particularly the 100-watt multiple type. To date these lamps have been placed on illuminating circuits in 630 cities and towns in not less than standard package quantities. In 295 cities and towns additional orders have been received from customers who less than three months ago placed orders for their first trial packages. There is no record of any place where the lamps are not giving satisfactory results. In one city over 2500 100-watt tungsten lamps have been ordered by one customer, and 11 other cities have each placed orders for over 500 lamps.

Very accurate reports have been received as to the breakage of lamps in transit; and this has averaged, on shipments to all parts of the United States, less than one and one-half per cent. The customer above referred to, who, as stated, has ordered more than 2500 lamps, reports that he has carefully examined those received and found that the breakage in transportation was less than 1 per cent. On over 1200 lamps sold and delivered to customers, including all lamps which burned out inside of 25 hours, the accidental breakage in handling was less than 1½ per cent., making the total breakage and early burnouts up to the time the lamp had lived 25 hours, a total of less than 2½ per cent.

The Company has just commenced to solicit orders for and make shipment of 60 and 40 watt lamps, and during the last ten days the orders for these types have amounted to over 22,000 lamps. The Company's total orders to date for the three types (100, 60 and 40 watts) have amounted to over 85,000 lamps, of which amount over one-half was sold during the month of March.

The tungsten lamp gives a light of high brilliancy and of agreeable color and quality closely resembling daylight, with the remarkable efficiency of from 1 to 1¼ watts per candle. Compared with the ordinary carbon filament lamp of equal life (3½ w.p.c.), for the same power consumption the tungsten lamp produces a superior quality of light of practically three times the volume of the former. The actual saving is 2.25 watts for every candle of light, giving a saving of 2.25 kilowatts hours for every 1000 candle hours.

The low resistance of tungsten necessitates a considerable length of filament for a 100–120 volt lamp; the filament is therefore made up of four or five hairpin loops connected in series, as shown in the accompanying illustration.



(Illustration ¾ actual size)
GE Regular Tungsten Lamp—100 to 125 Volts—100 Watt—80 C.P. (Mean Horizontal)

The Tungsten lamp is serviceable on both alternating and direct current, and gives equal life — approximating 800 hours — on both. Tests conducted show a remarkably slow and small decline in candle-power during life; so small that well-made lamps can be satisfactorily used until they burn out.

HORIZONTAL TYPE OF CURTIS STEAM TURBINE

By Richard H. Rice

The phantom illustration of a small direct current Curtis turbine set on page 246 shows the simplicity of the unit. The principal rotating element, so far as operating conditions are concerned, is practically a single piece, made up as it is of a shaft carrying armature, commutator and two turbine wheels. As this shaft is carried in only two bearings, which number would be required for the armature alone in the case of an ordinary generator or motor, the addition of the turbine driver has obviously not complicated the rotor from an operating standpoint. As a matter of fact, the presence of the turbine wheels has simplified the bearing problem, by reason of the fact that the center of gravity of the rotating system has been brought within the main bearing; and, therefore, since it is the only bearing carrying any weight, it is the only one requiring any special means of lubrication.

The special means of lubrication provided consists of a small gear pump located on the lower end of the vertical shaft driving the governor and valve gear. This vertical shaft receives motion from the main turbine shaft through a worm and gear, the worm being placed adjacent to the main bearing. In addition to the very slight amount of power required to operate the pump, the vertical shaft has only to rotate the inertia governor and supply an occasional momentary impulse to open or close one of the number of small governing valves which admit or shut off steam from the nozzles of the turbine. The light load on the worm gears, and the ample lubrication provided are responsible for the ascertained fact that the wear on these parts is imperceptible. Measurement on a set after two years of operation failed to reveal any appreciable wear; the teeth of the worm and gear were both within the original limits. Altogether, some hundreds of worm drives of this character are in operation throughout the country, and not one has ever had to be replaced.

The main bearings are similarly long-lived. The high speed of the shaft, when ample lubrication is supplied, is a positive advantage, since the shaft forcibly draws into the bearing a substantial quantity of oil, and therefore always runs on oil, and never touches the bearing. There is consequently no wear of the bearing.

The steam using elements of these turbines should be compared with those involved in the operation of reciprocating engines, if the chief advantages of the turbine are to be realized. In the case of the reciprocating engine, a definite quantity of steam is measured off for each stroke; this quantity of steam is then confined in the cylinder behind the piston and allowed to expand as the latter moves onward to the end of the stroke. Exhaust then takes place, and a new quantity of steam is admitted to the opposite side of the piston for the next stroke. It will be seen that, for the proper performance of this cycle, tight valves and tight pistons are essential. This prime essential is, however, difficult to secure; in fact, it is impossible to secure this condition permanently where any form of valve is used sliding on metal surfaces. As soon as motion begins, wear begins also; and experience shows that this wear is very rapid at first, gradually decreasing to some minimum rate if reasonable lubrication is secured. As a result, the steam consumption of single-cylinder engines increases rapidly from the time they are first put into operation; this increase varying from 10 to 40% in amount, depending on accidental conditions of lubrication, quality of metal, etc. Another cause of leakage often difficult to deal with is that occasioned by the warping of the valves and seats. This warping is caused by the temperature and pressure of the steam, and naturally is a variable quantity, depending upon the character of the design, and to some extent upon the foundry operations.

The admission valves for the steam turbine, on the other hand, are simple poppet valves which do not require lubrication, and which wear very slightly, always remain tight, and are not affected by warping. Once past these valves, the steam acts on buckets which never touch any other part of the mechanism. It has been demonstrated, that the running clearance between the revolving buckets and the nozzles and intermediates, can be made so great, without loss of efficiency, that destructive contact will never occur, and all these machines are now made in this manner.

Some small loss might be anticipated from leakage past the diaphragm packing from the first to the second stage. On small turbines this packing is made of carbon rings which wear for a long period without leakage, and which are easily renewed when necessary. The condition of this packing as regards tightness is always revealed by a simple inspection of the stage pressure corresponding to a given number of first stage valves open.

The only remaining source of possible loss is that which would result from direct wear of the buckets themselves. A few cases of bucket wear have been noted in turbines equipped with steel buckets, due to excessive quantities of moisture in the steam. It has, however, been demonstrated that considerable wear of these edges may take place without a perceptible loss of efficiency.

This wear is apparently due to the rusting of the steel forming a coating which is blown off by the moist steam, and as often renewed. Probably this rusting only takes place when the turbine is standing still. At any rate, the use of bronze buckets, now standard and universal on all Curtis turbines, entirely eliminates it.

The condensing Curtis turbine, size for size, is more economical than the best reciprocating engine. Non-condensing, with steam pressure best suited for it, the Curtis turbine is equal to the average high-grade non-condensing engine when the latter is new, and is superior to the latter in economy after a comparatively short period of service, even under conditions best suited to the reciprocating engine; while from the standpoints of durability, simplicity, ease of operation, attendance, cost of supplies, good governing, and all-around availability, the turbine is the superior.

THE MERCURY ARC RECTIFIER AND ITS USE WITH SMALL DIRECT CURRENT MOTORS

By W. F. Sneed

The mercury arc rectifier has been before the public now for about four years, and during that time it has been adapted to many cases where it was found necessary to rectify alternating current into direct current; in every case it has given satisfaction and has gained for itself quite a favorable reputation, and to-day is about as well known as any other piece of electrical apparatus.

Fig. 1. Monotype Keyboard Operated by Motor Driven Air Compressor

There are two distinct types of mercury arc rectifiers—the high potential or constant current type, and the constant potential variable current type. The former is used for rectifying constant alternating current into constant direct current for operating direct current series arc lamps, while the constant potential type is used for rectifying power from a constant potential alternating source into constant potential direct current. This latter type has been used for charging automobile storage batteries, telephone batteries, signal batteries, ignition batteries, and batteries used for many other purposes. It has also been used for operating direct current multiple arc lamps, induction coils, small power motors, and dental motors.

At the Norwood Press, Norwood, Mass., a mercury arc rectifier was recently installed for operating a number of 230 volt direct current motors. These motors, nine in number, are of rather small capacity, the largest being a ½ h.p. GE motor used for driving a ventilating fan. The other eight are ¼ h.p. GE motors, and are used for driving casting machines of monotype composing sets. The

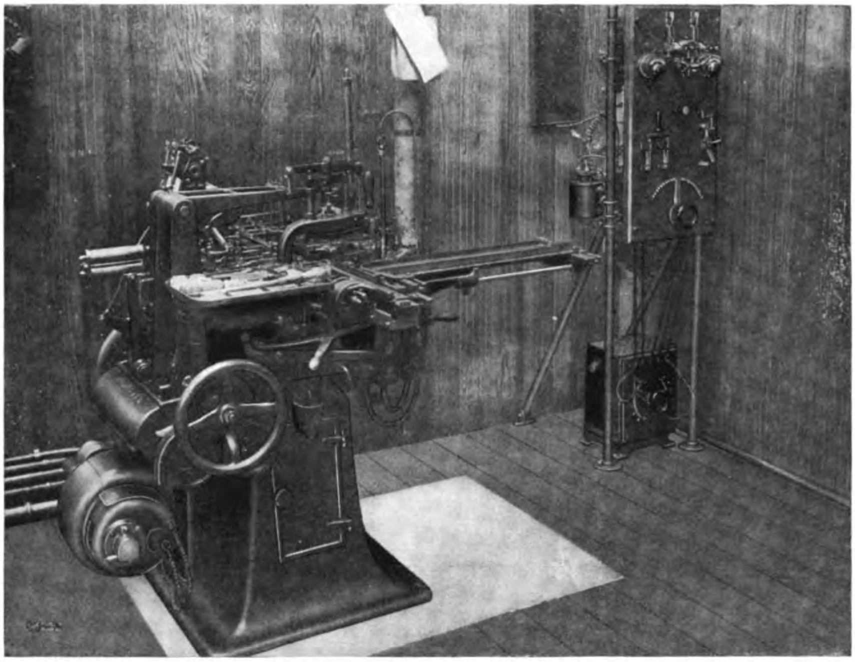


Fig. 2. Mercury Arc Rectifier and Motor Driven Monotype Machine, Norwood Press, Norwood, Mass.

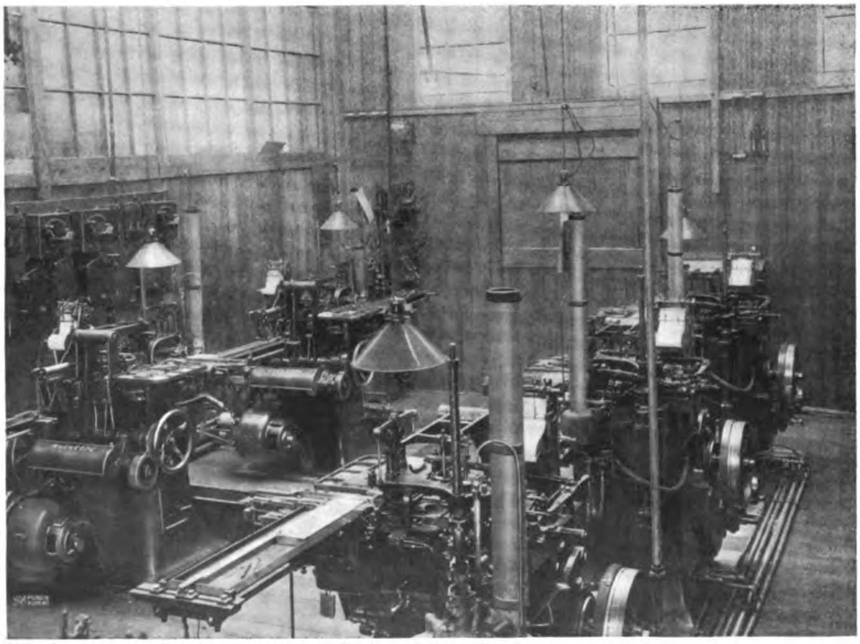


Fig. 3. Group of Monotype Machines Operated By Motors Driven from Mercury Arc Rectifier

rectifier is operated from a 525 volt 60 cycle alternating current supply source, and delivers direct current to the motors at 230 volts. The motors were originally supplied with direct current at the proper voltage from the Electric Power Company, but as the power system was recently changed from direct to alternating current, it became necessary to make some arrangement for driving the casting machines, either by changing the motors or by furnishing some kind of rectifier, and as the latter was the cheaper, as well as the better arrangement, it was adopted. The rectifier installed at the Norwood Press is the first application of this kind to small motors, and is a modification of one of the standard constant potential types. It is so arranged that any number of the motors can be thrown on or off as desired, without causing any interruption to the service whatever.

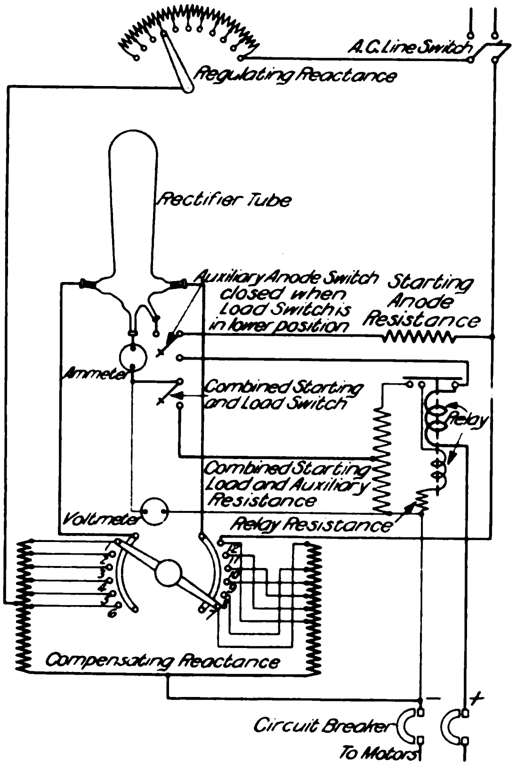

A.C. Line Switch
Regulating Reactance
Rectifier Tube
Auxiliary Anode Switch closed when Load Switch is in lower position
Starting Anode Resistance
Ammeter
Combined Starting and Load Switch
Relay
Combined Starting Load and Auxiliary Resistance
Voltmeter
Relay Resistance
Compensating Reactance
−
+
Circuit Breaker
To Motors

Fig. 4. Diagram of Connections

The complete equipment, shown in Fig. 2, consists principally of the following parts: rectifier tube; tube holder; compensating reactance and switch; regulating reactance and switch; starting load resistance; starting anode resistance; auxiliary load resistance; opening circuit relay; alternating current line switch; combined starting and load switch with auxiliary anode switch; panel and panel supports, etc. The connections for the outfit are given in Fig. 4, which shows clearly the function of each part of the apparatus.

The method of operation is simple, and follows in general the method used for the standard rectifier outfit; *i. e.*, close the circuit breaker and the alternating current line switch; hold the starting switch in the lower position and rock the tube gently until the mercury in the cathode makes and breaks contact with the starting anode, causing a flash which will start the tube on the starting load resistance. When the hand is removed from the starting load switch it will fly into the upper or load position, and thus transfer the rectified current to the auxiliary load resistance, and at the same time energize the motor buses. The motors can then be started when desired. The relay is so adjusted that it will open the auxiliary load circuit, as well as the shunt winding of the relay, when the current taken from the rectifier reaches the stable current of the latter, thus reducing the auxiliary losses to a minimum. It was found that the load taken by the fan motor was sufficient in itself to maintain the arc in the tube and to hold the relay open, and as it is necessary to always have the fan running while the casting machines are in operation, the attendant makes it a practice to start the fan motor first and the other motors as they are needed. If for any reason the fan motor and a sufficient number of the other motors are shut down to reduce the current taken from the rectifier to a value near the stability current of the tube, the relay will close the auxiliary load circuit, and the latter will take enough current from the tube to maintain the arc. All the motors may then be shut down for any length of time, and started up again without having to restart the rectifier. Of course, if the motors are to be off for any length of time, such as at noon hour, the rectifier should be shut down and restarted when needed, as it is much cheaper to restart the rectifier than it is to let it run on a dead resistance load for any but short intervals of time.

As the auxiliary load is used only as stated above; *i. e.*, at starting, and in cases of emergency, it is safe to state that the efficiency of this outfit is practically the same as the standard outfit when run at 230 volts direct current, which is about 82 per cent.

AN ELECTRICALLY-DRIVEN PORTABLE ELEVATOR

By J. S. Baker

In a large majority of the factories, warehouses and shipping depots engaged directly or indirectly in handling and storing commodities, loading and unloading steamboats, barges, cars, drays, etc., the work of moving the wares and produce is done mostly by hand.

In the Northwest, the speedy and economical stacking and handling of vast quantities of wheat, the principal product of that section, often assumes a serious aspect; and in the South, owing to the steady increase of wages, the same problem exists with regard to rough rice.

Recognizing the demand for a machine that would accomplish this sort of work at a reduced cost and at a more rapid rate than the existing method, with less work on the part of employees, the Brown Portable Elevator Co., of Portland, Oregon, invented and placed on the market a few years ago a portable elevator that is well adapted for transferring and elevating boxes, barrels, bales and sacks of a weight not exceeding 300 pounds.

The original portable elevator was designed for piling wheat in sacks, to a depth of 25 sacks, each sack containing from 100 to 150 pounds of wheat. The successful performance of this machine induced owners of warehouses and others interested in handling products other than wheat, to make requests for elevators for handling various shapes and weights, with the result that to-day the Brown Portable Elevator is found stacking barrels filled with flour, sugar, feed, bran, etc., bales of hay and fodder, and boxes containing articles of almost every description. Only minor changes were necessary in the original design to render the elevator suitable for handling the different shapes and weights.

In some of the larger grain handling firms on the Pacific Coast, as many as 25 of these elevators are to be found in use.

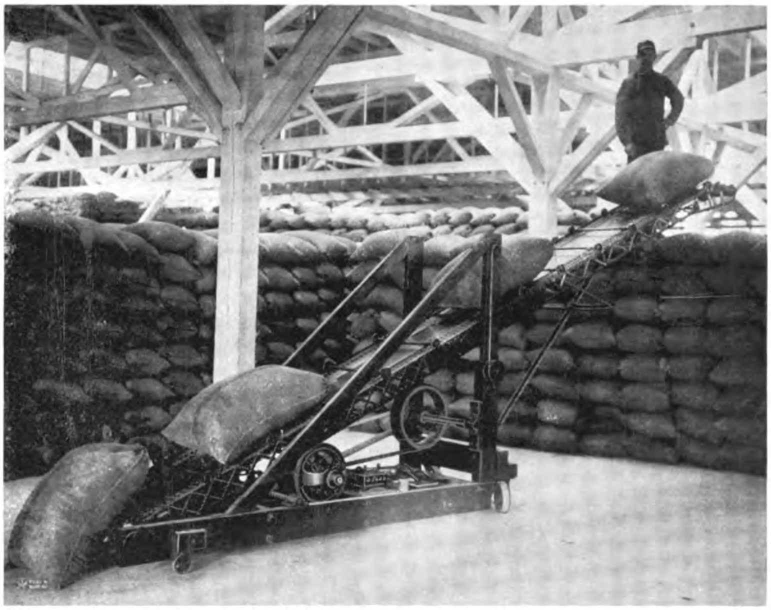


Fig. 1. Brown Portable Elevator Stacking Rough Rice in Sacks

Fig. 1 shows a Brown Portable Elevator, driven by a General Electric direct current motor, in the process of piling rough rice in sacks weighing 150 pounds. Fig. 2 shows a like machine designed for handling bales of hay, fodder, etc. The latter machine is shown driven by a General Electric alternating current motor.

The machines are usually supplied with 2 or 3 h.p. motors, and have a capacity for piling of about one ton per minute. Only two men are required to operate the elevator

—one to load, the other to pile—the man trucking ordinarily doing the loading. The same work if done by manual labor alone would require six men; it is therefore seen that the machine saves for its owner the wages of four men, which amount to from $6.00 to $10.00 per day, depending upon the scale of wages in different sections of the country.

As may be seen from the illustrations, a wooden platform or frame, on which are mounted the motor, starting apparatus, and driving axle, forms the base of the machine. This base is fitted with roller casters at or near each corner, by virtue of which the machine may be readily moved from place to place. To the front or receiving end of this frame is pivoted the lower end of the conveyor platform, or runway. This runway is supported at its upper end by two grooved wheels which bear on the under rails of the steel lattice work forming the sides of the runway. These wheels are mounted on an axle which is part of a steel rod brace, the lower end of this brace being pivoted to the rear of the base. To the ends of this axle are attached steel cables, which pass back parallel to and on each side of the conveyor platform, and are wound on small winch heads, located on the sides of the runway at a distance from its lower end equal to about one-third the length of the platform. By winding or unwinding these cables, which operation may be done by means of a ratchet device, the height of the delivery platform may be varied at will. Passing around the runway are two endless link belts, and attached to these at regular intervals are the carriers, which are supported on wheels running in steel guides.

The Brown Portable Elevators, as originally built, were fitted with gasoline engines, and even now, in certain sections of the extreme Northwest where electricity is not available, these engines are employed for driving the machines. Where electric power is readily obtainable, however, the makers warmly recommend the electric motor, as much for its reliability of service as for the reduced fire risk ensured by its use. Owners of large warehouses are averse to the fire hazard occasioned by the use of gasoline engines in the vicinity of dry and dusty materials, where the liability of fire, due to the cigarettes and pipes of the workmen, is already great.

The electric motor is the safest, most serviceable and satisfactory source of motive power available at the present day, and is especially desirable for service such as the above.

The leads are flexible and can be readily connected to the power circuits that are almost always to be found in or near large industrial centers.

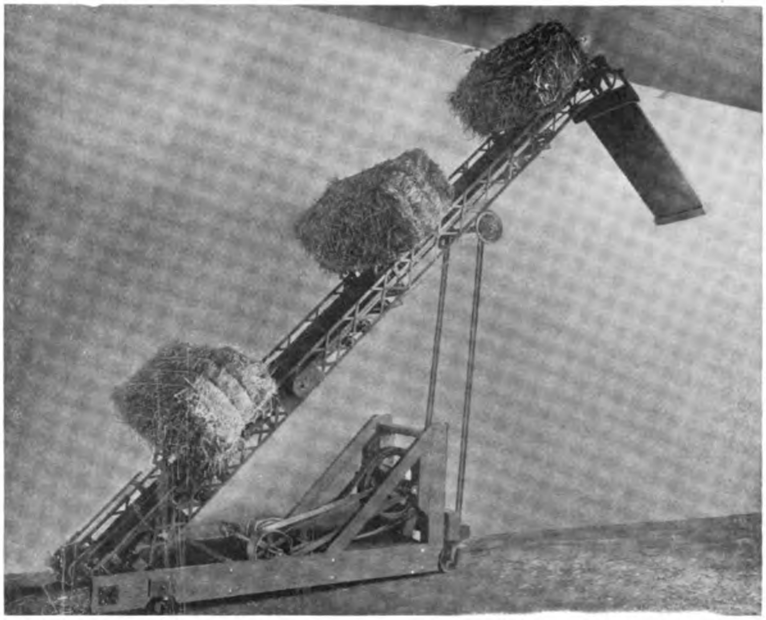


Fig. 2. Portable Elevator for Elevating Bales of Hay, Fodder, etc.

TYPE DP PORTABLE INSTRUMENTS

By D. P. Burleigh

Type DP direct current portable instruments have been designed by the General Electric Company for laboratory and general testing purposes. They are constructed on the D'Arsonval principle, in which a coil of wire carrying the current to be measured, or a shunted portion of it, is wound on a rectangular aluminum frame which is so mounted in jewelled bearings that it is free to rotate in the annular space between the pole pieces of a powerful permanent magnet and a soft iron core.

The entire mechanism is enclosed in a soft iron case which protects the instrument from the influence of magnetic fields, which are always present in the neighborhood of electric currents. The indications are rendered perfectly dead-beat by Foucault currents set up in the aluminum frame upon which the moving coil is wound. Errors due to paralax are eliminated by the use of a mirror situated under the scale.

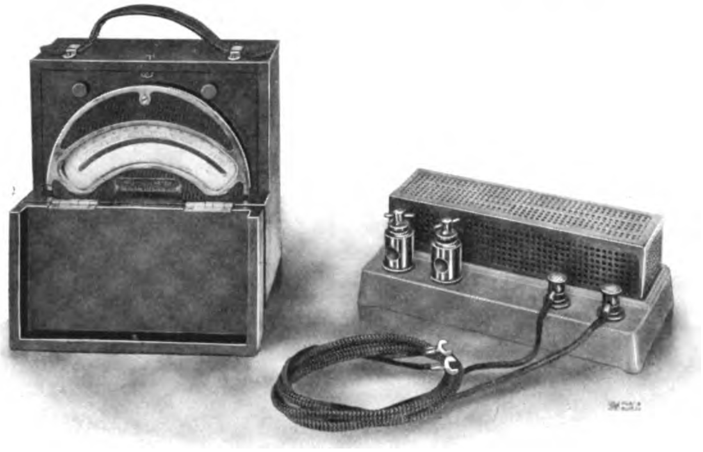


Fig. 1. Type DP Milli-Voltmeter and Shunt

The magnets are made from the best grade of magnet steel obtainable, and are subjected to various processes of ageing and hardening which insure their permanency. A liberal amount of iron is used in the magnets, providing a strong field and a high torque with a generous air gap, the latter feature reducing to a minimum frictional errors which might otherwise assume large proportions due to dust or other foreign particles lodging between the pole pieces and the coil.

A complete line of DP instruments will be manufactured, consisting of ammeters, voltmeters, milli-ammeters and milli-voltmeters. The ammeters are made self-contained up to and including 30 amperes. For higher ranges a milli-voltmeter with portable shunt will be furnished, the scales being marked directly in amperes.

These shunts are designed to give a uniform drop of 200 milli-volts at full load current. They are made of a metal having practically a zero temperature coefficient, and are free from errors due to thermo-electric currents. Thus, the instruments used with these shunts are practically free from errors due to changes in temperature.

The portable shunts are mounted on a base made of an aluminum alloy combining lightness with durability, and are protected by a perforated sheet metal casing. If desired, shunts can be furnished with two or more capacities combined in one case, thus adapting the instruments for a wide range of current. For use with these shunts, the milli-voltmeter is provided with a scale marked to agree with one of the capacities, and when connected to taps of different rating, the indications of the pointer are multiplied by the proper constant.

When instruments are desired for a class of work which does not require extreme accuracy, the milli-voltmeters may be provided with an extra binding post, so that they can be used in connection with ordinary station shunts, giving full scale deflection when subjected to a drop of 60 milli-volts.

ROTARY CONVERTERS

PART V

BY ERNST J. BERG

Effective Resistance and Reactance of the Armature

In connection with the discussion of the heating of the armature conductors it was found that the effective resistance, depending upon the number of phases used, was different from the resistance for direct current. The true copper loss, with non-inductive load, is equal to the square of the direct current multiplied by the effective resistance. This gives the following values for the copper losses in the different rotaries:

Single-phase	rotary,	1.414 ×	ohmic	resistance
Three-	"	0.55 ×	"	"
Four-	"	0.377 ×	"	"
Six-	"	0.266 ×	"	"

The armature self-induction can be calculated in the same manner as the self-induction of an alternator. For a distributed winding such as is used with rotary converters the self-induction is very small, usually in the neighborhood of 2 per cent., and can for most purposes be neglected.

Control of Voltage of Rotary Converter

Unlike the alternating or direct current generator, where the voltage changes almost in proportion to the change of field excitation, the direct current voltage of the rotary converter is only very slightly affected by a change in field strength, assuming, of course, that the rotary is supplied with alternating current at constant voltage.

The slight change in ratio between the alternating and direct current voltages is due to the internal drop in the armature, which depends upon the effective resistance and the armature self-induction. With a weak field, the rotary takes a lagging alternating current which causes a drop of voltage in the armature, whereby the direct current voltage is made less than it would be if the field excitation were such as to correspond to non-inductive or leading current.

Thus, for a constant direct current voltage, a higher impressed alternating current voltage is required with weak field than with strong field excitation.

A considerable change in the direct current voltage can, however, be obtained by placing a reactance, consisting usually of ordinary reactance coils, in series with the alternating current lines to the rotary. The amount of change in this case also depends upon the excitation, which controls the amount of wattless current.

Voltage Characteristic

The general equation showing the relation between currents and electromotive forces is given below:

e_0 representing the generator voltage;
e the alternating current voltage which corresponds in value to the direct current voltage;
i the alternating energy current;
i_1 the wattless lagging current;
$I = \sqrt{i^2 + i_1^2}$
r the total resistance between the two electromotive forces, e_0 and e;
x the total reactance between the two electromotive forces, e_0 and e;
$z = \sqrt{r^2 + x^2}$

We have then:

$$E_0 = e+(i+ji_1)(r-jx) = e+ir+i_1x-j(ix-i_1r)$$

and
$$e_0 = \sqrt{(e+ir+i_1x)^2 + (ix-i_1r)^2} \qquad (9)$$

This equation enables us to determine what the generator voltage should be for any value of e; that is, for any direct current voltage; or, solving the equation for e, we get:

$$e = -(ir+i_1x) + \sqrt{(ir+i_1x)^2 + e_0^2 - I^2z^2}$$
$$= -(ir+i_1x) + \sqrt{e_0^2 + 2ii_1rx - i^2x^2 - i_1^2r^2}$$

(Equation 10)

To study the range in voltage that can be obtained on the direct current side at no load, without external reactance, we will consider the following practical case.

Let the effective resistance of the armature be 2 per cent. and its reactance 2 per cent. We have then

$e_0 = 1$
$r = 0.02$
$x = 0.02$
$i = 0$ (since no load is considered)

Referring to equation 10 we have:

$$e = -0.02i_1 + \sqrt{1 - .0004\, i_1^2}$$

thus for $i_1 = 1$ we get $e = 0.98$
$i_1 = 0.5$ $e = 0.99$
$i_1 = 0$ $e = 1$
$i_1 = -0.5$ $e = 1.01$
$i_1 = -1$ $e = 1.02$

A range of 4 per cent. can, as a maximum, be expected, and with a reasonable amount of wattless current—say ½ of the full load value—a range of only 2 per cent.

As a second example, find the change in ratio with load; that is, with energy current only.

We then have: $e = -.02i + \sqrt{1-.0004\ i^2}$
at no load $e = 1$
and for $i = 0.5 = \frac{1}{2}$ load $e = 0.99$
$i = 1 =$ full load $e = 0.98$

Thus the ratio changes 2 per cent. with load; or, in other words, for constant alternating current voltage the direct current voltage drops 2 per cent. between no load and full load.

The change in voltage will be much greater if considerable reactance exists between the generator and rotary converter. To illustrate this, assume that the rotary is supplied with power over a line of 8 per cent. resistance and 18 per cent. reactance, in which case, due to its own resistance and reactance, the total resistance is 10 per cent. and reactance 20 per cent. Find the change in direct current voltage, with constant generator voltage, with a change of wattless current from the full load lagging to the full load leading value, for the following conditions:

1st. With no load on the direct current side.

2d. With full load on the direct current side.

In the first case the equation becomes:

$$e = -i_1x + \sqrt{e_0^2 - i_1^2r^2} = -.2i_1 + \sqrt{1-.01i_1^2}$$

In the second case:

$$e = -(.1+.2i_1) + \sqrt{1 + .04i_1 - .04 - .01i_1^2}$$

The results obtained are tabulated below:

At No Load		At Full Load	
For $i_1 = 1$	$e=0.795$	$i_1 = 1$	$e=0.695$
$= 0.5$	$e=0.898$	$= 0.5$	$e=0.789$
$= 0$	$e=1.000$	$= 0$	$e=0.879$
$= -0.5$	$e=1.098$	$= -0.5$	$e=0.968$
$= -1$	$e=1.195$	$= -1$	$e=1.054$

It is thus seen that in this case the voltage can be varied 20 per cent. either way, and that in general (subject to small error only) the change in voltage is governed by the product of the reactance and the wattless current.

Thus, if it is desired to raise the voltage 10 per cent., it may be done with full load leading current and 10 per cent. reactance, or with one-half of the full load leading current and 20 per cent. reactance.

Too much wattless current is undesirable on account of the increase in armature heating (especially near the taps to the collector rings), and too much reactance on account of the stability of the converter.

As a reasonable reactance, 15 or 20 per cent. may be assumed, which can be made up of the line reactance proper, the reactance of transformers, choke coils, etc.

Phase Characteristic

One of the most interesting and important features of synchronous apparatus, such as synchronous motors and rotary converters, is its ability to take current of various power factors, depending upon the excitation.

There is a certain excitation at which the alternating current is a minimum, and corresponds to the actual load. Increasing the excitation beyond this value causes a leading current to flow; decreasing it, a lagging current.

The magnitude of the wattless current can be obtained directly from the synchronous motor equations by inserting the "effective" resistance and reactance previously discussed.

Since, however, the effect of the resistance is slight, a very close approximation can be obtained by a relatively simple calculation.

Armature Reaction

If there were no magnetic leakage between the field poles, and if, therefore, the whole magnetomotive force of the field was available at the armature surface, the effectiveness of the armature reaction (which is to say the armature magnetomotive force), would be the same as that of the field poles for the same number of ampere turns. As it is, the effectiveness of the field magnetomotive force is from 10 to 20 per cent. less than that of the armature magnetomotive force, and therefore, with a field excitation of F ampere turns, the effective value can be assumed as only $0.85\ F$.

Let F_0 denote the resultant magnetomotive force of field and armature.,
F the field excitation.
R the armature reaction, or armature excitation with full load current.

We then have: $F_0 = 0.85\ F + R$.

To illustrate these characteristics, a 300 kw., 600 volt, three-phase rotary converter will be used. This machine has an armature reaction of 3820 ampere turns and a no-load excitation of 6300 ampere turns with 600 volts at the commutator.

Fig. 18 gives not only the calculated, but the actual test results, the former being shown in dotted and the latter in full lines. Since in the test the direct current voltage was kept constant, the equation

$$e_0 = \sqrt{(e + ir + i_1x)^2 + (ix - i_1r)^2}$$

has been used.

The voltage characteristic is calculated on the basis of 2 per cent. resistance and 2 per cent. reactance; and the phase characteristic on the basis of the armature reaction and no-load excitation given above, with a magnetic leakage coefficient of 15 per cent.; in other words the effectiveness of the field magnetization is assumed as 85 per cent. of that of the armature.

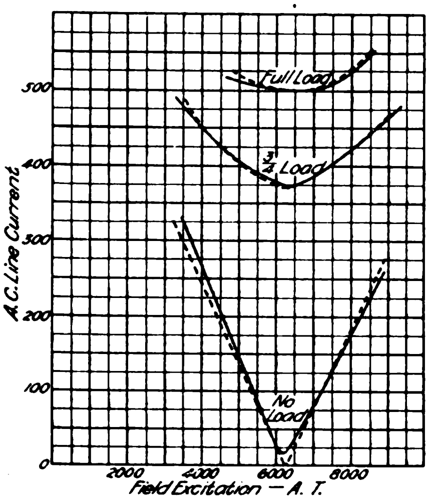


Fig. 18. Phase-Characteristic of 300 Kw. Rotary Converter

Since in the test the phase characteristics are plotted with the actual field excitation as abscissas, and the armature current as ordinates, it is convenient to consider the armature reaction as 15 per cent. more effective than the same number of ampere turns on the field, instead of the field excitation as 85 per cent. of its actual value.

Therefore we may write: $F_0 = F + 1.15\,R$.

In this particular case $F_0 = 6300$, and the full load alternating line current is

$$\frac{300{,}000}{\sqrt{3} \times .615 \times 600} = 470 \text{ amp. at } 100\% \text{ eff.}$$

The armature reaction can be expressed as the product of a constant k (which depends upon the winding), and the wattless alternating current. Thus at full load current:

$$1.15 \times 3820 = 470\,k, \text{ and } k = 9.35.$$

The general equation for any wattless current becomes: $6300 = F + 9.35i_1$

$$\begin{array}{lrlr}
\text{Thus for } F = & 2000 & i_1 = & 460 \\
= & 4000 & = & 246 \\
= & 6000 & = & 32 \\
= & 6300 & = & 0 \\
= & 8000 & = & -182 \\
= & 10000 & = & -395
\end{array}$$

The full load and fractional load phase characteristics are obtained by vectorially combining the wattless current with the energy current. So, for instance, at full load we get

energy current $i = \dfrac{470}{0.94} = 500$ amp. (assuming 94 per cent. efficiency).

Thus for

$$\begin{array}{rlllr}
F = 2000 & \text{total cur. } I = \sqrt{i^2 + i_1^2} & = 680 & \text{amp.} \\
4000 & \text{"} \quad \text{"} \qquad \text{"} & = 557 & \text{"} \\
6000 & \text{"} \quad \text{"} \qquad \text{"} & = 500 & \text{"} \\
6300 & \text{"} \quad \text{"} \qquad \text{"} & = 500 & \text{"} \\
8000 & \text{"} \quad \text{"} \qquad \text{"} & = 532 & \text{"} \\
10000 & \text{"} \quad \text{"} \qquad \text{"} & = 640 & \text{"}
\end{array}$$

Fig. 18 shows the close agreement between the calculated and observed value.

(To be continued)

A SIMPLE AND EFFECTIVE LAMP BRACKET

By G. H. Stickney

The accompanying illustration (Fig. 1) shows a convenient form of lamp bracket for suspending lamps from walls or poles. It is common practice to suspend arc lamps on brackets so that they hang four or five feet from the bracket support, but with this arrangement it is often quite difficult to reach the lamps for trimming. The special feature of this bracket is that it permits the lamp to be swung up close to the support, where it can easily be reached from a ladder leaning against the latter. When hung from a wall it is sometimes convenient to trim a lamp from a window; and it is likewise often desirable to trim a lamp from a pole. The construction of the bracket and its operation are so convenient that the device is sure to appeal to a practical man.

The bracket consists merely of a piece of gas pipe bent and mounted as shown in the sketch. The lamp is suspended by means of a pulley arranged to run on the pipe. When the lamp is in its regular position, the pulley rests in a shallow loop formed in the pipe, this being sufficient to keep the pulley firmly in place. A stop can be provided to prevent the lamp from striking the support.

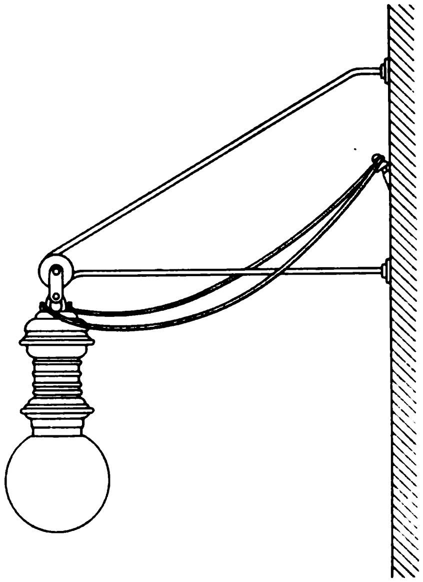


Fig. 1. Arc Lamp Bracket in Regular Use by The Detroit Edison Illuminating Co.

From the above, it will be seen that the device can readily be made in any pipe shop without special tools.

It is in regular use by the Detroit Edison Illuminating Company, having been described to the writer by Mr. W. B. Thompson of that Company.

NINTH MEETING PITTSFIELD SECTION A. I. E. E.

On March 27, the Pittsfield Section of the A. I. E. E. held its first annual banquet. One hundred and nine members of the local section were present and enjoyed a very pleasant evening. An excellent dinner was served, after which Mr. Joseph Insull called upon Mr. R. W. Pope, the speaker for the evening, who responded in his usual happy manner, mingling many laughable stories and anecdotes with his reminiscences of the growth of the Institute and his connection with the work.

Mr. Pope began his electrical career in Berkshire County, and was quite at home in a Pittsfield audience. He described a number of the advantages to be gained by joining the Institute, and stated that no electrical engineer could afford not to join.

Mr. C. C. Chesney told of pioneer local developments in alternating-current generators and transformer design dating back to 1883—one of these generators having been in regular service ever since.

Mr. W. S. Moody spoke of the electrical engineer as a business man, and told several stories illustrating his point that the successful engineer of the day is generally a shrewd man in business matters.

Mr. W. S. Andrews of Schenectady described some of his varied experiences with Edison at Menlo Park in the early days of electric lighting. His witty remarks elicited much laughter and applause.

Mr. H. W. Tobey made a few remarks urging the local members to join the National body, and to take active part in the meetings.

In addition to the speeches, entertainment was furnished by Mr. A. V. Thompson of Schenectady, and Mr. Boland of Pittsfield, who gave several songs and responded willingly to vigorous encores.

BOOK REVIEW

STANDARD HANDBOOK FOR ELECTRICAL ENGINEERS

McGraw Publishing Co. 1300 Pages Price $4.00

This is by far the best book of the kind that has yet appeared, the only one comparable to it being Hütte's Ingeniers Taschenbuch.

The subject matter is divided into twenty sections, each section being treated as a separate unit, and in many cases these have been specially written by recognized authorities. The sections are further subdivided into numbered articles.

A casual examination of the ordinary handbook is apt to create the impression that it must contain all data that can ever be required; but when, subsequently, the engineer has occasion to consult it for some specific information, he finds, too often, that the particular item wanted has been omitted, or if not omitted, is next to impossible to locate.

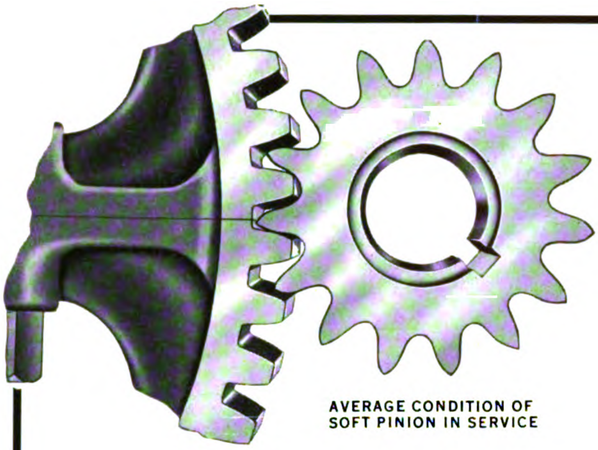
The new handbook, however, is particularly satisfactory in this respect. The information is very complete, and the division by sections and articles, together with the excellent typographical arrangement, makes it possible to locate quickly any desired fact. An exceptionally full index still further facilitates rapid reference. The index references are given by section and article number instead of by page—a system which is in a measure less convenient but which lends itself well to frequent revision, as does the sectional arrangement of the book as a whole.

The diagrams and curves seem to be the weakest feature of the book; the former are in many cases, unworkmanlike and crude, while the latter would have been greatly improved had they been shown on a larger scale.

On the whole the book is one that is likely to become its owner's *vade-mecum* and to find a place on his desk rather than on his book shelves. It is certainly well worth the price that is asked for it.

Railway Motor Gear Economies

Why use a worn pinion with a new gear when the new GE long life "Grade F" Pinion will last substantially as long as a cast steel gear?



AVERAGE CONDITION OF SOFT PINION IN SERVICE

Consider the inefficiency of gears operating under these conditions — the abnormal demand on the power station — the racking wear on motors and trucks — the noise and annoyance to passengers — all due to the loss of original accuracy of tooth dimension

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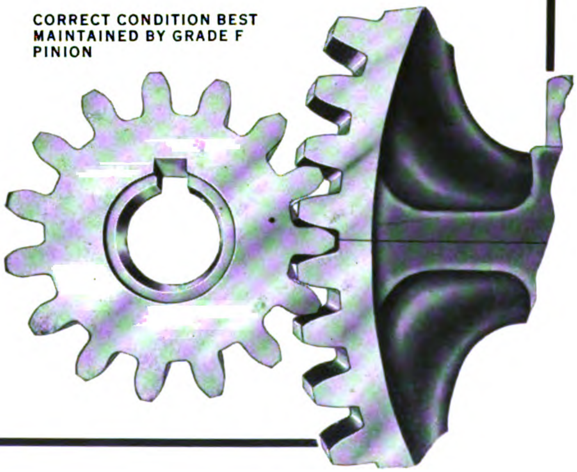

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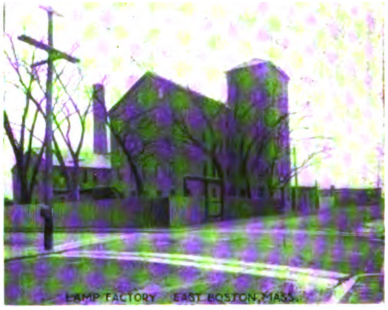

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GENERAL ELECTRIC REVIEW

VOL. X, No. 7

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SCHENECTADY, NEW YORK

JUNE, 1908

LIGHTNING FLASHES

(See Page 299)

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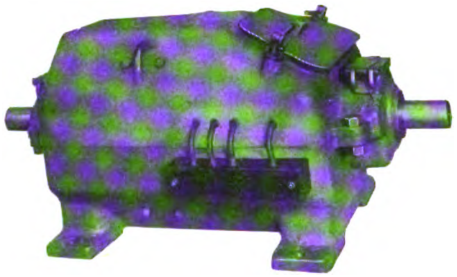

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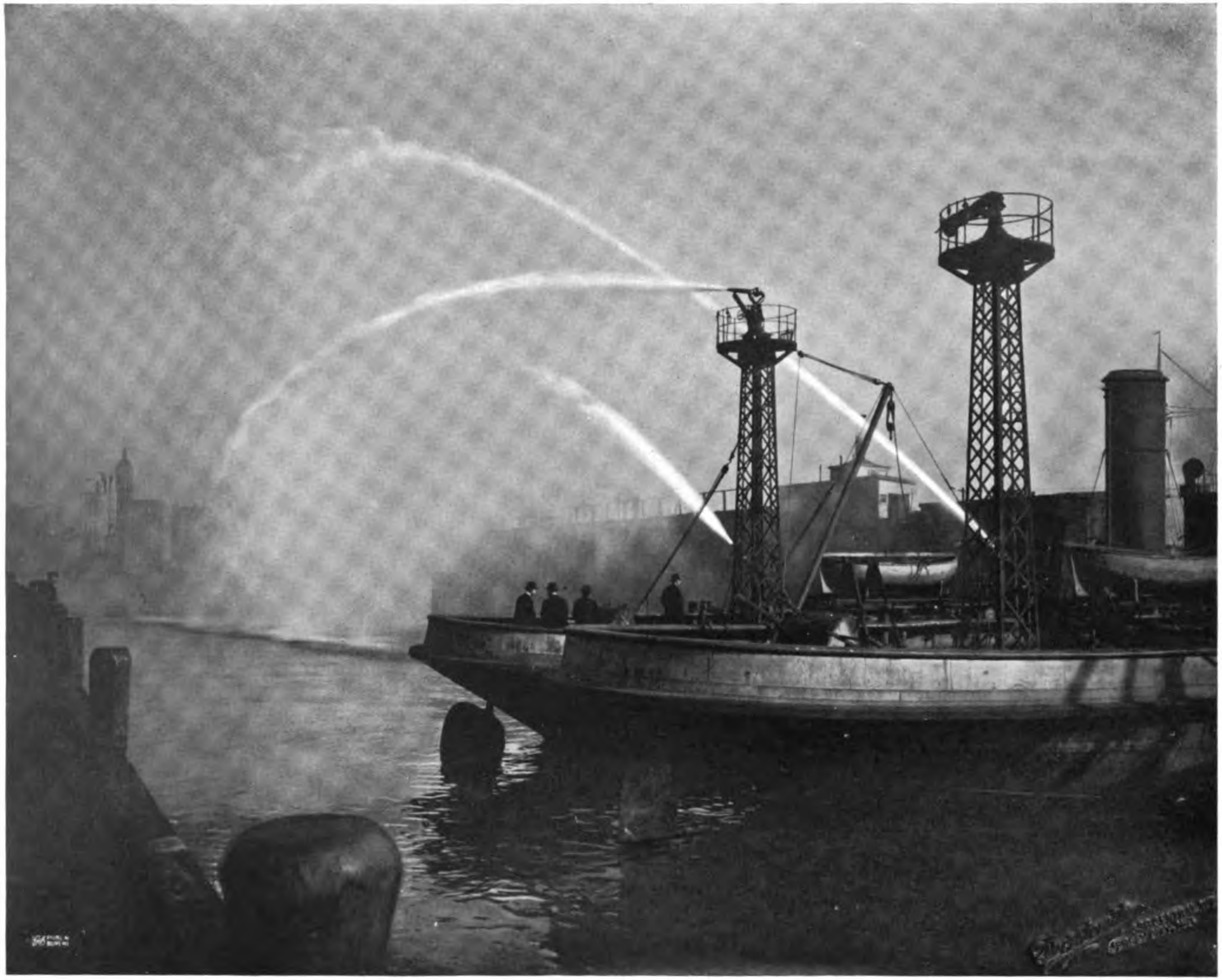

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(See page 339)

GENERAL ELECTRIC
REVIEW

LIGHTNING PHENOMENA AND LIGHTNING ARRESTERS

By E. E. F. Creighton

Power and Mining Department, General Electric Company

It is the object of this paper to give a general review of the more important results of the study of lightning phenomena that have been obtained during the past year; to describe the usual lightning troubles that occur on most transmission systems, and to show briefly how lightning arrester design has been made to meet the requirements of protection. In a paper written for the annual meeting of the A.I.E.E., June 1908 the forms of apparatus used for studying lightning in Colorado during last summer are described. It is not the object of this paper to show how these measurements were made, but simply to give a review of the results obtained and refer the engineer who is further interested to the more detailed description in the institute paper.

Since the Colorado tests show many of the conditions which have to be met, they will be reviewed first. The five principal factors studied are:

1st. Duration of the surge of lightning.
2d. Potential values of the lightning.
3d. Maximum current discharge rate.
4th. Natural frequency of the lightning.
5th. Quantity of electricity in the lightning stroke.

The Duration of Lightning

The duration of lightning on the transmission line was measured by means of a spark gap in front of a rapidly revolving photographic film. Out of three dozen discharges, the usual duration of a single stroke was in the neighborhood of one one-thousandth of a second. The longest single stroke of induced cloud lightning recorded was 0.04 second. The principal factors which control the duration of discharge of induced cloud lightning are as follows:

(a) The actual duration of the discharge of the cloud.
(b) The nearness of the cloud to the line.
(c) The initial induced potential on the line.
(d) The earth resistance between the point of cloud discharge and the point of the discharge through the arrester. In other words, the value of resistance which controls the logarithmetic decrement of potential of the discharge.
(e) The value of the gap setting of the arrester or measuring apparatus.

(*a*) The actual duration of the usual stroke of cloud lightning we know from many observations is comparatively short. A fairly authentic record of one stroke of the order of a half second has been made. Such a length of duration, however, is rare, and careful measurements seem to indicate that such a duration is only the effect of multiple strokes, or successive discharges from the clouds. So long as the oscillations take place between the cloud and the earth, the potential will be impressed upon the transmission line in the form of forced oscillations. If the stroke of lightning is between clouds in a horizontal direction parallel to the line, then the induced potential on the line must necessarily die away with the cloud lightning discharge. This is a case of electro-magnetic induction. If, on the other hand, there is a quantity of static electricity induced on the line by the cloud and freed when the cloud discharges, it is possible for this freed charge to oscillate after the surges from the cloud have entirely disappeared. The duration of the line discharge will then depend upon the initial voltage and the damping in the path of the surge of lightning current.

(*b*) and (*c*) Factor b may in reality be considered under factor c, in that the voltage of the oscillation will depend upon the nearness and the intensity of the discharge. It is evident that a cloud of a given dimension will induce a higher voltage if it is near the line than if is it far away. With the same damping of the surge on the line the discharge at the higher potential will have a longer duration. Storm clouds differ enormously in size and in capacity. A single cloud was observed which was a small patch in a clear sky. This cloud discharged to earth with a stroke of small volume. Larger clouds were observed from which heavy strokes took place, which in turn caused other clouds to discharge to them, giving multiple strokes to earth. It is evident from this that the quantity of electricity induced on the line will vary greatly with the form of the cloud, as well as the distance from the line.

(*d*) If the charge of lightning is freed at some distance from the station, this charge on the line has a complimentary charge on the surface of the earth which is held by static attraction. As this charge on the line moves along the line toward the station, it drags its complimentary charge along the ground through the comparatively high resistance of the surface of the earth. How much the charge on the earth will penetrate as it moves along under the line is an unknown factor, but it is evident that this resistance is far greater than the resistance usually found in the earth connection of the lightning arrester. The subject will be further treated under "Potential." This surface resistance of the earth is the factor damping the discharge on its way to the arrester. On the other hand, if the cloud should happen to be directly over the station or lightning arrester, this damping factor will evidently be very much less, due to the fact that the resistance of the surface of the earth is reduced to a proportionally less value.

(*e*) In the measurements made on the line the gap setting was about 10,000 volts. It is evident that when the potential on the line reduces to 10,000 volts, the line will cease to discharge across the gap, whereas if the gap had been short circuited, the surge would continue until zero potential was reached. Assuming the damping factor constant, the duration of the discharge from the line is determined by the ratio of the initial to the final potential.

So far, we have considered the duration of a single stroke. It is found, however, from measurement that the usual conditions in a large storm produce many multiple strokes. As many as eight successive strokes were recorded in an interval of less than a second. There were several cases where four strokes were distributed over one second. So far as the lightning arrester is concerned these multiple strokes give the effect of long duration of discharge. In the discharge of the multigap arrester, a successive stroke which follows at any time later than half cycle and less than the time necessary to cool the cylinders, will have somewhat the same effect as a discharge which continues over the length of time between the successive strokes. This factor of multiple strokes must be considered in the design of arresters and a corresponding endurance obtained. There seems to be no doubt that an occasional failure of an arrester has been due to some severe condition of successive strokes. In certain classes of storms these successive strokes take place slowly enough to be observed visually. They seem to be due to the readjustment of potential between clouds. For example, a cloud discharges and releases the potential strain in its neighborhood. The static electricity which, up to this time, had been distributed over the face of the adjacent cloud next to the earth or other oppositely charged clouds, now is drawn through the high internal resistance of the cloud toward the one which has just discharged and has been reduced to earth potential. It seems that this readjustment in the non-discharged clouds requires an appreciable time. Finally the static strains between this cloud and the one discharged is sufficient to cause a cloud to cloud discharge, which readjusts temporarily the potential in this locality but causes another stroke to earth. This process is repeated indefinitely until all the clouds in the neighborhood have readjusted their potentials with the original discharging cloud.

There is a third consideration of duration of lightning which comes under the head of continual lightning. Continual lightning usually occurs from an internal source. The usual cause is a grounded phase through an arc. The duration of this kind of discharge depends entirely upon the circumstances. So long as the arc to ground takes place there will be lightning more or less severe according to the local conditions, and this lightning will continue until the trouble is removed from the line. During the measurements last summer aluminum lightning arresters were in operation continuously for periods ranging from forty seconds to a half hour.

Potential Values of the Lightning

The maximum potential value that a lightning charge can have on the line will result from a direct stroke. The usual effects of a *heavy* direct stroke are well-known. The lightning jumps over the insulators and down the poles to the earth. If the stroke is not heavy enough to jump over the insulators to the earth, then it will spread over the line and the lightning arrester has an opportunity to carry the discharge to earth. These induced potentials may have all values ranging from the spark voltage from line to ground through the insulation and poles, down to insignificant values. The observations of last summer show conclusively that the potential on the line nearest to the clouds is the peak value, and when the charge is freed it spreads gradually over the line, giving at every other point a lower potential. If there were no resistance in the path of the complimentary charge on the surface of the earth, this high peak of potential would travel undiminished in a wave along the line to the end. If the storm occurs over the station the lightning arrester in the station must take care of this excessive peak potential. The difference in the requirements to discharge under these two conditions of nearness or distance of the lightning storm really comes under the consideration of the maximum current discharge rate (the 3d heading).

From the measurements of quantity of electricity, estimates were made of the maximum potential which might occur for a given stroke. A value was estimated at 600,000 volts. It occurred on a wooden pole line insulated for 50,000 volts. The question whether this high potential will jump over the insulators to ground is not solved by impressing a test voltage of 600,000 on the line, because the conditions would be entirely different. The potential from a lightning stroke is due to the quantity of freed electricity, which initially may not cover over a mile or so of line. This quantity of electricity is connected directly with the total capacity of the line and its natural tendency is to spread out over the line. If the inductance of a straight line is sufficient to hold the potential at the insulators at this spark value, for a time equal to the dielectric-spark-lag, then the insulator will spark over, otherwise it will not. In other words the danger of sparking at the insulators is a matter of the relative time constant of the line to the dielectric-spark-lag of the insulator.

In connection with this subject of the arcing at the insulators, a digression in this discussion is made to describe some tests which gave concrete figures on the value of a wooden cross-arm relative to a metal cross-arm as an extra protection against lightning. A wooden cross-arm was arranged as shown in Fig. 1: two porcelain tubes held wires 1.7 in. above the surface of the wood and ten inches apart. On the upper surface of the wood either tin-foil or a wet towel was placed in imitation of line conditions. The first test on this cross-arm was made on a 60 cycle circuit with a needle gap in parallel with the cross-arm. The spark voltage was the same whether the wet cloth or the metal was used. By transformation the voltage was 46,900, and by needle gap it was 3.5 ins., (52,000 volts by interpolation from the curve). This high indicated potential by the needle gap is due to local oscillations set up by corona discharges over the porcelain tube. The disruptive discharge circuit was then made up as shown in Fig. 1. The natural frequency of discharge was 2.25 million cycles per second. The applied potential was a 4.5 in. gap between spheres 1.25 in. in diameter. When the cloth was used very wet the equivalent-needle-gap was 5.6 in. (68,000 volts). When the metal plate was used between the porcelains, the equivalent-needle-gap was only 2.5 in. (45,000 volts). Summarizing this we have the following:

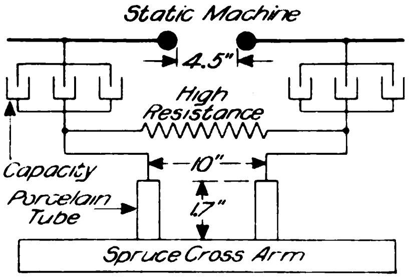

Fig. 1. Connections for Disruptive Tests of Insulators on Wooden or Metal Cross-Arm

VOLTAGE

	60 Cy.	E.N.G.	2.25 Million Cy.	E.N.G.
Metal cross-arm	46,900 52,000	3.5″	42,000	2.5″
Wet wood arm	46,900 52,000	3.5″	68,000	5.6″

It will be noticed that the spark potential of the metal cross-arm is actually less at high frequency than it is at normal line frequency. This phenomenon is due to the double gap between line and line and no connection of the metal plate to earth. The metal cross-arm has a static capacity which takes an appreciable charging current across the gaps. The action is similar to the action in the multigap arrester. In regard to the interpretation of the test it is well to note that 5.6 in. was the limiting potential at which the needles would spark over, the actual conditions would have been even more favorable to the wet wood if the applied potential had been greater. Taking it as it was, the wet wood cross-arm was 160 per cent. better than the metal as a protection against high frequency lightning, and the metal cross-arm was only 80 to 90 per cent. as good for lightning as it was for dynamic potential. If the wooden cross-arm were not saturated with water, there would be of course greater protection than shown by these experiments.

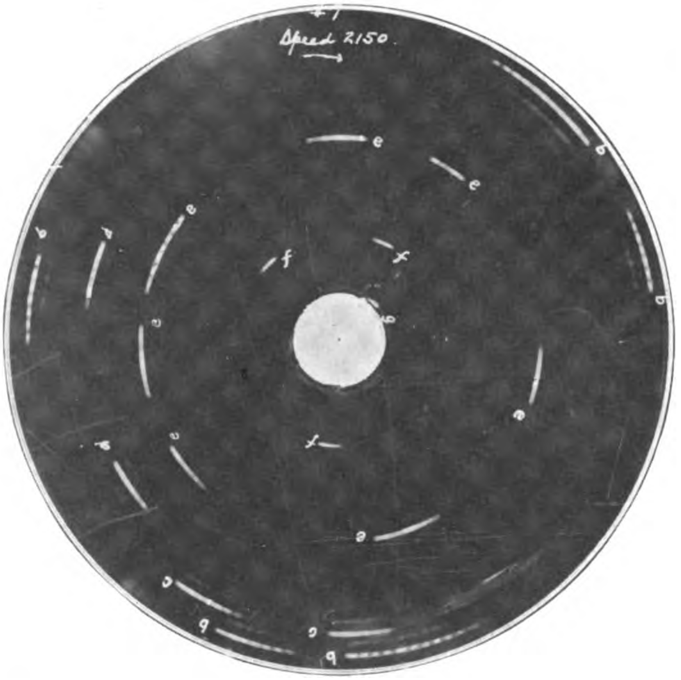

Fig. 2. Record Taken from a Revolving Film Duration Apparatus

Impressions having the same radius are due to multiple strokes occuring in a fraction of a second. The duration of each stroke can be calculated from the velocity of rotation

Although these figures will no doubt be somewhat modified by changing the relative conditions of the test, it is safe to conclude that the wooden cross-arm is always to be recommended, and would be a most desirable and economical feature even on iron towers. It is usually cheaper to add insulation with wooden cross-arms, than it is to obtain it with added porcelain in the insulator. These tests have a bearing on the use of insulator horn-gap protectors that will be apparent to the engineer.

Maximum Current Discharge Rate

In this discussion the subject of direct strokes from a cloud will not be considered. The rate of discharge of an induced current on the line is nearly always definitely fixed. Since it is the maximum value of the current passing through the resistance of the lightning arrester causing the menace, the following equation is given for the maximum rate, on the assumption that the resistance is negligible.

I max. = $v\sqrt{\frac{C}{L}}$, where C is either the capacity per unit length of the line, or the total capacity of a condenser; and L is correspondingly the inductance of a unit length of line, or the concentrated inductance in a coil. In the high frequency circuit in the laboratory the maximum current is 0.03 ampere per volt impressed; consequently, at the value of 100,000 volts impressed, the maximum possible rate of discharge is 3000 amperes. The value of current is actually somewhat less than this on account of the resistance of the circuit and the spark. On transmission lines the maximum possible current of a discharge coming from a distance out on the line is of the order of 0.002 ampere per volt impressed. Therefore, in order to produce a current of ten amperes the impressed potential would have to be 5000 volts. Ten amperes is the current limitation at double normal voltage of some of the old types of arresters. In order to get a current discharge of 1000 amperes, the applied potential must be at least 500,000 volts. This is the value of current discharge of the aluminum arrester at double normal voltage.

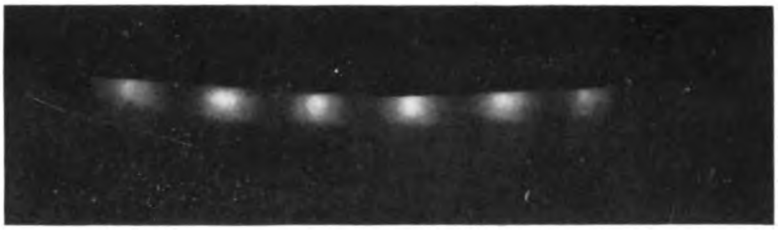

Fig. 3. Enlarged View of One Discharge Taken from the Record Shown in Fig. 2

Since the spark is extinguished every half cycle, no impression is made on the film at this time; this makes the record of discharge a broken line

If, however, the lightning cloud is over the station or arrester, then the maximum possible rate of discharge may be somewhat greater than the value given above, on account of the fact that the average inductance of the line wire in the path of the discharge is less than in the previous case considered. Furthermore, it has already been noted in the paragraph on potentials that the maximum potential of the lightning is invariably greatest under the discharging cloud; consequently the rate of discharge of the arrester must be greater on account of the higher induced potential.

The Natural Frequency of Lightning

The frequency of lightning may be considered under four heads.

1st. The frequency of recurrence of the lightning stroke. For example, lightning strokes often come into a station during a storm at an average rate ranging from two per minute to one in five minutes. Since lightning arresters are, without question, designed to take lightning discharges as frequently as given, this condition will not receive further attention here.

2d. Each of the flashes that appear to the eye as a single flash is often several distinct strokes distributed over a fraction of a second (Fig. 2). The bearing that these multiple strokes have on lightning arrester design has already been discussed under the heading of duration.

3d. Each individual stroke may be analyzed into frequencies of the order of the natural frequency of the line. This was done in the Colorado tests by means of a rapidly revolving film in front of a spark gap, as described under the heading of duration. Fig. 3 shows a record from one of these machines. The impression on the photographic film is in the form of a broken line. The parts of this broken line represent the half cycles of discharge of lightning over the line through a single gap to ground. This line was not connected to generators. The accuracy of measurement is not high, so the frequencies recorded are divided into seven groups. One stroke at 840 cycles per second, eight strokes at about 1400, six strokes at about 2000, two strokes at about 2500, twenty strokes at about 3000, and one stroke at about 4000 cycles per second. The natural frequency of the line was in the neighborhood of 1800 cycles. All of these records were taken from discharges that were generated by clouds located five miles or more from the station.

4th. At the point underneath the cloud, it is very probable that a frequency as high as one million cycles per second was impressed on the line, due to the induction from the cloud. The potential of such a high frequency would be greatly diminished as it travels along the line. However, it has been mathematically demonstrated in the study of telephonic transmissions, that high frequencies travel along the line faster than low frequencies. Therefore, such a high frequency would reach the lightning arrester before the main body of the charge and would consequently be effective in starting the discharge over the multigap arrester.

In order to prove out that this high frequency exists on the line, a special form of high frequency meter was designed, working on the principle of interference of traveling waves, or in other words, stationary waves. This instrument had a number of coils resembling the pipes of a church organ, each one responding to its individual frequency and over tones. Due to the initial experimental difficulties with this apparatus and the natural condition of discharge on a long line, only two of the many records taken were of value. Both of these records show frequencies of the order of a million cycles per second.

Quantity of Electricity in the Lightning Stroke

By means of fuses and the duration meter, the quantity of electricity to blow a fuse can be found. Its value $Q=\sqrt{\frac{Jt}{R}}$, where J is equal to the energy in joules necessary to raise one centimeter length of fuse metal to its melting point, t is the duration of discharge, and R is the resistance in ohms per centimeter length of fuse metal. The joules of energy necessary to melt the fuse can be found by calculation of the metal used, or by actual calibration by the use of an oscillograph. The average effective quantity of lightning (q) passing through a fuse is equal to Q divided by the number of oscillations shown by the revolving film. If the number of oscillations are few, this calculated value is approximately equal to the original quantity on the line freed by the cloud discharge.

Using the data taken from a number of tests, and making approximate calculations, it is found that the ordinary induced charge of lightning may initially have surprisingly high voltage. In one calculation of a fairly heavy discharge, the estimated initial voltage was of the order of a half-million volts.

Summarizing some of the essential parts of the foregoing discussion we have: that the strain on the lightning arrester will depend on the size of the storm cloud, the nearness of the cloud to the line, the distance of the storm away from the arrester, the resistance of the surface of the earth, the condition of the multiple stroke and the time elapsing between them, and the condition of continual lightning. The effects of these factors may all be grouped under three heads:

1st. The spark potential of the arrester.

2d. The factors which relate to the rate of discharge of the arrester.

3d. The factors which relate to the duration of the discharge of the arrester.

1st. The arrester must be capable of sparking over at a voltage which is within the safe value of the insulation.

2d. It must have a resistance low enough to discharge the maximum rate of current that could flow to that point.

3d. It should have a duration sufficient to discharge so long as the potential is dangerously high.

For many years the presence of continual lightning on a transmission line was not fully understood. Lightning arresters were designed *par force* for transitory lightning. The multigap arrester is distinctly a transitory lightning arrester. It can not be expected to carry the discharges which occur on a system from continual lightning. With the graded shunt resistance on the multigap arrester, light discharges may be taken through the high resistance for an appreciable time reckoned in seconds, but through the low resistance the amount of energy dissipated is large, and consequently the duration of the discharge must be correspondingly small. The question may pertinently be asked, "Why not design the multigap arrester to carry continual lightning?" The multigap arrester is intrinsically not suited for such a condition. While it might be possible to design the arrester with sufficient metal in the cylinders which form the gaps, and sufficient radiating surface of the resistance to carry the current for a considerable time, it would make the cost of the arrester prohibitively high. The arc extinguishing quality of the multigap arrester depends, to a considerable extent, on keeping the cylinders cool and limiting the amount of molten metal in the gaps where the arcs take place. It is evident that no arc can play across the gap for any considerable time without producing a disadvantageous amount of molten zinc. Furthermore, the cost of the resistance alone designed to radiate the necesssarily large amount of dynamic energy would make the arrester too expensive. Attention was turned to the type of arrester which was intrinsically suited to discharge continual lightning, and has resulted in the development of the aluminum arrester.

Before describing the aluminum arrester, a partial review will be made of the usual demand of protection on a system in a territory where lightning is fairly frequent. Since by the law of chance only a small percentage of the lightning storms will pass directly over the station, it is safe to assume that the lightning arrester will usually be called on to discharge only about 0.002 ampere per volt of lightning potential. Incidentally, this may explain why the resistance type of arresters have given such good results. Since the peak of lightning potential occurs immediately under the cloud, the arrester at one station cannot be expected to give protection to any other station at some distance away. It is necessary to install an arrester at every point where apparatus is to be protected.

Occasionally, through a broken insulator, a transformer bushing, or a switch bushing, one phase of a non-grounded neutral system will become grounded through an arc. This arcing ground will send a series of surges throughout the entire system. It is necessary to have a lightning arrester on the circuit which will discharge the abnormal voltage for a long enough time to permit the operator to locate and isolate the trouble. It is estimated that, in general, a half hour should be sufficient to do this. If the trouble occurs at some sub-station the information can usually be received immediately. If there should be an auxiliary transmission line, the damaged line can be switched out within a half hour. If, however, the trouble should occur on a single transmission line, a half hour will usually allow a patrolman to travel out toward the trouble. In such a case it is desirable to have the duration of the arrester longer than a half hour to give the patrolman more time. These factors have been kept steadily in view in the design of the aluminum arrester. Since the conditions to be met are so variable, this fact has resulted in the design of several types of aluminum arresters. In all of these arresters, the aluminum cell is the basis of design, and consequently they have certain common characteristics. The characteristics of the aluminum cell will be described, and subsequently some of the variations in the design of the arrester to meet the demand of practice.

The useful characteristic of the aluminum cell is its critical voltage. This critical voltage depends upon the formation of a hydroxide film of aluminum on the surface of the aluminum plates. The plates are put through chemical and electro-chemical treatments until this film is formed. After this, the plate, dipped in a suitable electrolyte, has a characteristic of taking exceedingly low currents up to its critical voltage, but above this critical voltage the current is limited only by the internal resistance of the elctrolyte. The closest analogy to this action is found in the well-known safety valve of the steam boiler, in which the steam is held back until the pressure rises to a given value, and is then released for all pressures above. On the aluminum plate there are myriads of these safety valves, so that if the electric pressure rises above the critical voltage, the discharge takes place equally over the entire surface. This phenomenon is visible to the naked eye. It is important to distinguish between the valve action of this hydroxide film and the failure of any dielectric substance like mica for example, which resembles somewhat the hydroxide film in chemical composition. If a thin sheet of mica has impressed upon it a voltage just sufficient to puncture it, say 20,000 volts, the failure will take place at a single point and the pressure will suddenly drop from 20,000 volts down to 20 or 30, which is the voltage necessary to maintain the arc between electrodes. On the other hand, if the pressure is gradually raised on the film of the aluminum cell, there is no single puncture point, and no decrease in potential when the film allows a heavy dynamic current to flow through.

The volt-ampere-characteristic curve of the aluminum cell will vary somewhat according to whether direct currents or alternating currents are used. If direct current is used there will be no current passing through the circuit except the tiny leakage current through the film; whereas, if alternating current is used the aluminum cell acts as a fairly good condenser, and there is not only the leakage through the film, but also a heavy capacity current flowing into the cell. The phase of this current, then, is nearly 90° ahead of the potential and represents a very low energy factor. A volt-ampere-characteristic-curve of the aluminum cell on direct current is shown in Fig. 4. The permanent critical voltage is shown as 420. This voltage will vary considerably with the nature of the electrolyte. A curve is shown of the current discharging above the critical voltage in Fig. 5. The data for this curve were taken with an oscillograph. Since the arrester will discharge high dynamic current for a brief interval, there is no doubt that it will take lightning discharges which are of less duration. In all of the designs, the number of cells for the circuit are chosen so that the average dynamic voltage per cell is always less than 420 volts, the permanent critical voltage.

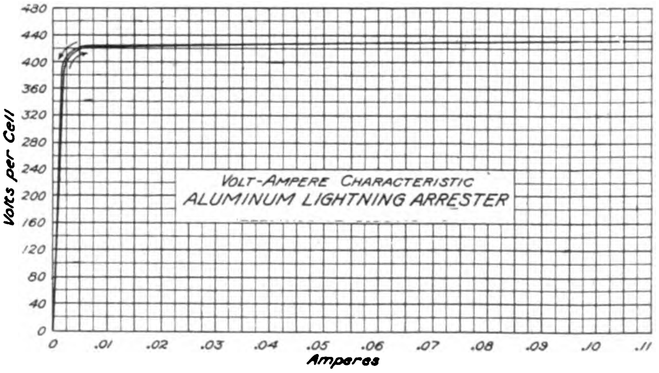

Fig. 4. Volt-Ampere Characteristic Curve of a 600 Volt D.C. Aluminum Arrester Drawn to a Large Scale

Another characteristic of the aluminum cell is the dissolution of a part of this film when the plates stand in the electrolyte and the cell is disconnected from the circuit. The film is composed of two parts; one part is hard and insoluble and apparently acts as a skeleton to hold the more soluble part. The facts connected with the action of the cell seems to indicate that the soluble part of the film is composed of gases in the liquid form. The dissolution of the film varies greatly with the nature of the electrolyte. When a cell, which has stood for some time disconnected, is reconnected to the circuit, there is a momentary rush of current which replaces the part of the film which is dissolved. In suitable electrolytes the duration of this current rush will be less than .01 of a second, even after the cell has stood over a week. This current rush will have increasing values as the interval of rest of the cell is made greater. Dozens of electrolytes have been studied, and there has been no electrolyte found which does not show this dissolution effect to a greater or less extent. The disadvantageous conditions produced by these current rushes are usually negligible. If the cell has stood disconnected from the circuit for several weeks, there is a possibility that the initial current rush will trip an instantaneous relay of a circuit breaker. This current rush also raises the temperature of the cell.

When a cell is connected permanently to the circuit, there are two conditions, which may be distinguished as *temporary critical voltage*, and *permanent critical voltage*. For example, if the cell has 300 volts, applied to it constantly, and the voltage is suddenly increased to, say 325 volts, there will be momentarily a considerable current rush, until the film thickness has been increased to withstand the extra 25 volts. This will take place at all voltages up to the permanent critical voltage which is about 420 volts. Above 420 volts the film cannot thicken appreciably. If the voltage is again reduced to 300, this excess thickness of film will be gradually re-dissolved. If the voltage is varying periodically between two values, each of which is less than the permanent critical value, the temporary critical voltage will be the upper value. This is a valuable characteristic of the cell. It provides a means of discharging abnormal surges the instant that the pressure rises above the normal impressed value. In comparison, other arresters usually require 100 per cent. or more rise in potential before the current begins to discharge.

Life of the Arrester

If the arrester is connected to the circuit continually there is a constant wear on the surface of the aluminum, and it is necessary to replace the aluminum plates from time to time. If, however, a gap is used in series, and the arrester brought into operation only at times of high abnormal voltages, there is no appreciable wear on the plates.

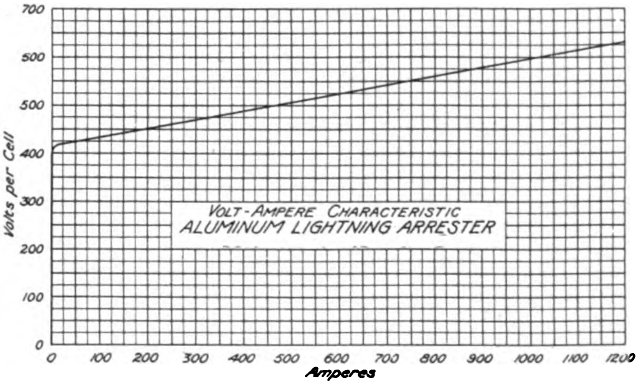

Fig. 5. Volt-Ampere Characteristic Curve of a 600 Volt D.C. Aluminum Arrester Drawn to a Small Scale, Showing the Rate of Discharge above the Critical Film Voltage

Choice of Design

The aluminum arrester, according to the design, will carry the current continuously for either a half hour or more, or six months or more. The financial investment here enters to determine which design shall be used. An aluminum arrester which is designed to carry the current continuously must be large to radiate the internal heat, and consequently relatively expensive. In certain locations it is of questionable value to install a costly arrester requiring some expense for the up-keep, in order to take care of discharges that probably occur not more frequently than once or twice during a year. It is better economy in this case to design an arrester which is connected to the line through a single series gap and comes into operation only at the time it is needed. In this case it need have only sufficient heat storage capacity to carry the discharge until the trouble can be removed.

To meet the usual conditions of transmission circuits, three main types of aluminum arresters have been designed. Each type will give different results by slight mechanical changes in its installation. The variations will be pointed out in the consideration of each. For the protection of over-head constant potential alternating current systems of all voltages from 2300 to 110,000 volts, the gap aluminum arresters have been designed. This arrester consists of inverted concentric cones slightly separated and partially filled with a suitable electrolyte. This stack of cones is then immersed in oil contained in an iron tank; the lowest cone is connected to the iron tank, and the upper cone is connected through a horn gap to one phase of the transmission line (Fig. 6). The connections of this lightning arrester for a delta circuit are shown in Fig. 7.

The two variable factors which can be adjusted by an operator to meet the local conditions are first, the gap setting, and second, the nature and quantity of the electrolyte. This arrester is designed primarily to discharge continual lightning for one-half hour or more. The total duration of discharge will depend on the initial temperature of the arrester, since the limitation is set by the final temperature. To obtain these conditions, it happens that the electrolyte chosen has an appreciable dissolving effect on the film, and therefore it is recommended that the arrester be connected to the circuit for a moment from time to time. Since, when continual lightning comes on to the circuit, it is advisable to start the arrester at a low temperature, it is well to keep the film in perfect condition so as to avoid the unnecessary heating of it due to a large initial current rush; therefore it seems advisable in most cases to make the test once each day. Incidentally, this has the advantage of forming a fixed habit, and of making the operator accustomed to the discharge condition of the arrester. Since the aluminum arrester is the only one designed for continual lightning, its series horn gaps should be set at values less then the spark value of the other arrester on the circuit designed for transitory lightning, so that it will protect the transitory arresters from destruction. For this kind of a disturbance, then, the aluminum arrester becomes a protector for the other arresters, and completes the protection of the system. How many aluminum arresters are necessary to do this depends on the size of the system, the voltage, the tendency to resonance on the circuit, and the severity of the arcing ground. The minimum number may be one.

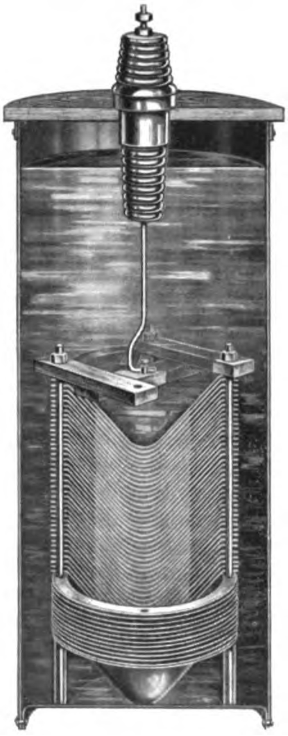

Fig. 6. One Phase Leg of a Gap Aluminum Arrester, Showing the Form of the Cones, Method of Holding them Apart, and the Position of the Electrolyte, Oil, and Tank

As a further consideration, since the time of discharge of the arrester is limited, it is necessary that an attendant shall be advised as soon as the arrester commences to discharge, so that he can take precaution to remove the trouble. Where the arrester is installed in plain view and in hearing of the attendant, its operation will make itself known to him immediately; if, however, the arrester is installed out doors or in an adjacent room, it is essential to use a lightning alarm in connection with the arrester. This lightning alarm consists essentially of two parts; an extra aluminum cell installed in the arrester circuit next to the earth, from which leads are run to an alarm bell, placed at any convenient place in the office or station.

The endurance of arresters to continuous discharge is somewhat indefinite since, as already stated, it depends on the initial condition of the arrester and the initial room temperature. Some idea of this endurance may be formed from life tests that were made on a 13,000 volt cone type arrester. The gap on this arrester was set below the spark potential of the circuit, and the arrester allowed to discharge in relays of *two* and *three* hours twice a day until the total length of discharge was 80 hours. At the end of that time the arrester was still operating normally. The cones were disassembled, and were all found to be somewhat worn by the passage of the current, but still in useable condition. It is estimated, however, that it would require many years to sum up a total of 80 hours of continual lightning on any circuit under normal operating condition. There is one feature of these tests that the operators should be acquainted with, namely: that after the cell has operated for a long time and heated up, the dissolution effect of the electrolyte on the film is abnormally great; so that subsequently, when the arrester has cooled down and is reconnected to the circuit for its diurnal test, there will be an abnormal current rush similar to that which would take place if the arrester had been left off the circuit for many days. This abnormal current rush can be entirely avoided, if the operator should feel it necessary, by taking the precaution of placing a resistance in series with the cells during the few moments of the first subsequent test. This brings up the question of what will take place if the arrester is left continuously on the circuit. It is recommended that the arrester may be allowed to discharge for half an hour without causing any serious trouble. If the operator should care to run the risk of allowing his arrester to discharge for a longer time, he may do so under certain circumstances; the action of the arrester will then be as follows:

The continuous passage of the current will continue to heat the electrolyte and oil, but the current will increase only slightly until a certain critical temperature is reached; then the current will increase quickly from about 1 ampere. normal discharge rate to the destructive value. If a fuse is placed in series, of a size large enough to take all known forms of induced lightning and recurrent surges, but small enough to disconnect the lightning arrester from the circuit in time to prevent permanent damage to the arrester, an interruption of service from a failure will be avoided, and the arrester may be put into serviceable condition again after it cools off. In order to overcome the natural prejudice against a fuse, it should be noted that the use of the fuse with this lightning arrester is under different conditions from its use with any type of resistance arrester.

In a resistance type of arrester of any value, there must be possible a large discharge rate of dynamic current, whereas in the aluminum arrester the dynamic current is limited to a very small value by the film, and it is only the lightning current of brief duration which assumes large values. A fuse will take high current for a brief interval without melting. It is then possible, at a slight risk, to operate the gap aluminum lightning arrester up to its limit of endurance without destruction of the arrester. While this recommendation cannot go out to operators in general, it may be used if necessary under conditions of peak load, where continuity of service is of great value.

The discharge rate of this arrester at double normal voltage is of the order of 1000 ampere, and the leakage current at normal voltage is less than one ampere.

Line or Unattended Arresters

When an aluminum arrester is located either on the line, or in the station where there are no attendants, it is evidently undesirable to have the arresters discharge continual lightning unbeknown to any one. If the arrester does this it will discharge until it is disconnected from the circuit by its series fuse. The first condition, then, in the installation of the arresters in this location is to increase the length of the horn gap to such a value that if continual surges occur on the line it will not discharge except for very abnormal peak values, and the lesser surges will be carried to the station arresters, where the discharge will be observed and precautions taken to remove the trouble. Since the arrester is to be used more or less in an intermittent capacity, and may not be inspected conveniently every day, the electrolyte is changed. An electrolyte is chosen which gives less dissolution of the film, so that it may be allowed to stand for a long interval without connection to the circuit and still not cause an inconveniently large initial current rush. In making this change, the discharge rate of the arrester is not diminished, in fact, it may even be increased if desired; the endurance to long discharge, however, is lessened. In all situations inspection is normally made at least once a week; consequently it is recommended that this line arrester be connected to the circuit once every week.

The value of oil in the arrester as an absorber of heat may be judged by the following test.

Two 2300 volt arresters, having equal internal resistance, were set up. One was filled by allowing the electrolyte to over-flow from the upper cone to the lower one, and a small amount of oil was then placed on top; the other was partially filled and immersed in a tank of oil. The arrester that was not immersed in oil operated fifteen minutes and then blew its fuse. The other arrester immersed in oil operated two days continuously, and did not blow its fuse at the end of that time. In other words, for this low voltage the surface of radiation was sufficient to keep the arrester within reasonable temperature limits. Since for higher voltages it is impossible to proportionally increase the radiating surface with the potential, this condition of radiation will not hold, and it is necessary to depend more and more on the heat capacity of the oil. While an aluminum arrester not immersed in oil answers very well for transitory lightning, it is not at all suited to taking care of continual lightning.

Horn Gap Switches

On account of the desirability of connecting arresters to the line from time to time, the horn gaps take new forms. The horn gap is arranged to fulfill three functions:

1st. As a horn gap, to prevent line voltage from reaching the arrester.

2d. A short circuiting switch, so that the operator may safely and easily connect the arrester to the line when desired.

3d. A disconnecting switch to isolate the arrester from the line when desired.

Two types of combination horn gap switches are shown in Figs. 7 and 8. For high voltages the revolving horn is used as shown in Fig. 8. For voltages up to 25,000, a tilting insulator is used to short circuit the gap, and the horn is arranged to act as a switch blade and to open in the vertical plane (Fig. 9).

On delta connected systems, or on systems with a neutral grounded through a high resistance, it is necessary to use an arrester leg connected between the multiplex and ground, in order to give the proper distribution of voltage in the cells during the condition of an accidental grounded phase. In the first arresters installed this grounded leg on the arrester was kept in condition by short circuiting each one of the phase gaps separately. In the later types auxiliary switches are inserted which exchange the ground leg with one of the phase legs during the interval of the test. One of these devices, the tilting insulator switch which accomplished this exchange, is shown in Fig. 9.

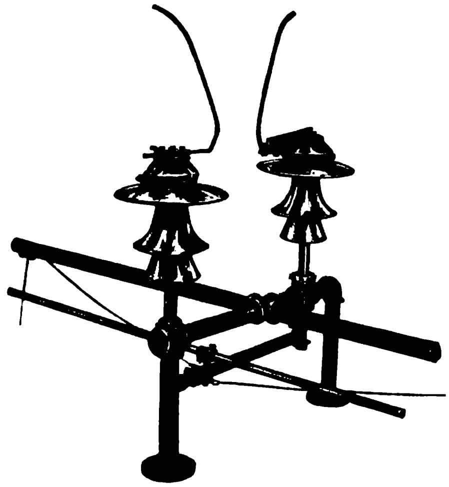

Fig. 7. A Skew Sketch Showing the Relative Connection of the Aluminum Arrester for a Non-Grounded Neutral Circuit, or a Circuit with the Neutral Grounded Through a Resistance

Aluminum Arresters for D.C. (the Second General Type)

The arresters for direct current have to meet more favorable conditions of internal loss, but more difficult conditions of delicate insulation to be protected.

The usual direct current circuit has a potential of 600 volts, and the insulation is usually double cotton covered wire; yet the motors carrying this delicate insulation are run out in the suburban districts where the induction from thunder clouds is as severe as found on a high tension circuit. To meet this condition the series gap of the arrester is abandoned, and the aluminum cells are connected directly between line and ground. A value of plate area is chosen which will discharge over 1000 amperes of current at double voltage (1200 volts). This effect is shown in the curve of Fig. 4. Some idea of the comparative value of this arrester is obtained from the current discharge rate relative to the arresters in present use. One of these arresters discharges 17 amperes and the other about 0.3 ampere of dynamic current, at double normal voltage. The leakage current through the aluminum arrester is never over a few milli-amperes, and is usually only one milli-ampere. Thus the increase of current from normal potential to double normal potential is a million fold. The equivalent-needle-gap of this arrester is 0″ as compared to 0.25″ for the older types of 600 volt arresters. The internal resistance is so low, and the inductive circuit so short, that the hands can be held across this arrester while a discharge of 100,000 volts at a frequency of about a million cycles from leyden jars is being discharged through it. In this type of arrester the effect of the temporary critical film voltage is prominent; it may be said that the arrester begins to discharge the instant the voltage rises one volt above normal. The capacity of this arrester as measured by the ordinary methods is equal to the electro-static capacity of 400 miles of trolley. The capacity is a combination of the electro-chemical and electro-static.

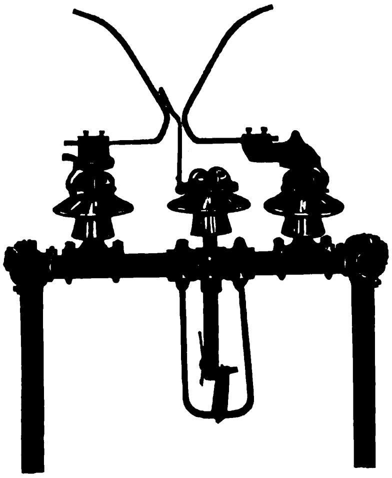

Fig. 8. Insulator Carrying a Horn Which Revolves Horizontally Around its Axis

When the horns are in line the gap length is less than the spark potential of the line, and in this position the arrester can be tested. The normal position for the horn is at an angle to the opposite horn, so that the gap setting is greater than the normal line potential. When used as a disconnecting switch the horn is swung around at right angles.

Induction of Connecting Leads of 600 V. Direct Current Arrester

While this arrester will discharge at a high rate of current and limit the voltage at its terminals to a very small value, it cannot, however, prevent a drop of potential in its connecting leads. At ordinary frequency, the drop in potential along even a small wire is of negligible value, but at high frequencies the voltage drop for even a foot of wire may become dangerous to cotton insulation. Some idea of what might take place may be obtained from the discharge of a leyden jar. With a circuit giving a frequency of 2.25 million cycles per second, it is quite easy to produce a drop of potential over one foot length of wire which will puncture four thicknesses of cotton covering. In other words, it will short circuit two adjacent wires, each of which is double cotton covered. While this condition evidently happens infrequently on the trolley circuit, it shows the advisability of taking the precaution to make the distance from the lightning arrester tap to ground as short as possible, as compared to the length of connection to the other apparatus. The ideal condition would be to install the arrester as near the motor frame and truck frame as possible, and bring the trolley lead down to the arrester and then back to the controller apparatus. Exactly how far it is necessary to reduce the inductance or length of the ground connection of the arrester, has not yet been determined. Unless the lightning conditions are unusually severe, no change in the present practise seems necessary. If, in any case extra precautions are necessary to lessen the inductance

ıey will be found in one or
ɔwing: (*a*) Flat strip used as
arth; or (*b*), connections to
: frame, and wheel, as well as
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cy of 2.25 million cycles per

[illegible] ins. wide and very thin, $\frac{3}{16}$ in.

5 ft. round No. 10 wire, $\frac{7}{16}$ in.

ERRATA Pages 310 and 311.

Title under Fig. 7 should be under Fig. 9
" " Fig. 8 " " " " 7
" " Fig. 9 " " " " 8

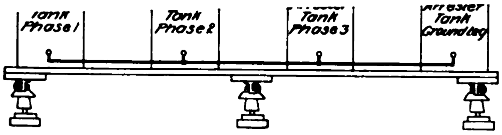


Fig. 9. Tilted Insulator Horn Gap

In this switch the horns are set in the same plane with the gap, at a setting somewhat above the line potential, so that the current will not flow into the arrester continuously. For the purpose of testing, an intermediate insulator is supplied which revolves around the horizontal axis, and by tilting carries a metal wire between the horns, and thus places the aluminum cell in contact with the line. For disconnecting, one horn is fulcrumed at the top of the supporting insulator and may be turned over backwards in a vertical plane.

When certain foreign substances are placed in the electrolyte, the aluminum cells fail by allowing a heavy current to flow through them. This brings the electrolyte up to the boiling point, and the cells boil themselves dry and finally open up the circuit.

Surge Protector

The third general type of aluminum arrester is the surge protector. The surge protector, like the direct current arrester, is connected directly to the circuit. The principal problem relates to the wear of the aluminum plates under the continuous scouring action of the alternating currents. The cone type of the arresters has been tested in service during several years, but the surge protector is more recent, and is now being tried out in service. The necessity for the surge protector is found principally on cable systems where the ratio of the capacity to the inductance is large, and consequently, where the surge current on the line will be correspondingly large for every volt of lightning potential.

Choice, Condition, and Location of Arresters

In the preceding discussion, an attempt is made to show briefly the variable demands on an arrester. Although no invariable rules can be made to include all cases, it is possible to cover most of them with the following directions.

On overhead systems use enough gap aluminum arresters to protect the entire system from an accidental grounded phase. Use these aluminum arresters in stations where there is an attendant, or where an auxiliary small wire may connect to an alarm in a house or office from which word can be sent to the nearest station that trouble exists on the line. In all such locations use normal electrolyte and a horn-gap setting of 125 to 175 per cent. of normal potential, according to the local conditions. In general, use the aluminum arrester where there is expensive apparatus. Move other types of arresters from important stations to places of less importance to give room for the aluminum arresters. Keep the aluminum arrester as cool as possible. Except in very sunny, hot countries, no unusual precautions need be taken.

In unattended stations or isolated installations, use modified electrolyte if tests cannot be made more frequently than once per week, and make the horn gap setting 175 to 225 per cent. of normal voltage. Use this type of installation, or the multigap arrester where overhead lines join cables.

For direct current railway circuits, the aluminum arrester becomes essential in suburban districts where lightning is frequent. On every direct current feeder circuit, use aluminum arresters in the stations, at least. Use aluminum arresters in any location where the resistance type is not giving complete protection. For complete protection, the established rule should be followed of placing one arrester on each car, and two per mile on the line.

On 110 volt direct current circuits use the no-gap 100-300 volt aluminum arrester to protect recording meters and other delicate apparatus.

THE LUMINOUS ARC LIGHTING OF TOLEDO

By C. R. McKay

A ten years' contract for the street lighting of Toledo became effective on January 1, 1907, between the City of Toledo and the Toledo Railway & Light Co.

This contract required the furnishing of 1375 arc lights of 2000 candle-power equivalent, to be burned nightly, from one-half hour after sunset to one-half hour before sunrise.

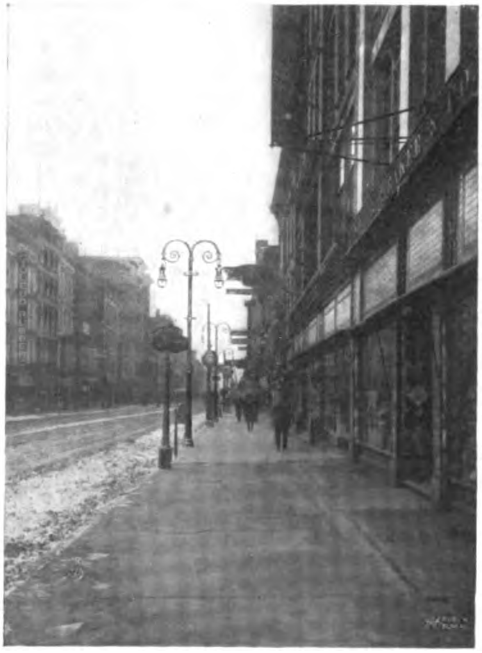


Fig. 1. Summit Street, Toledo. Showing Ornamental Poles Supporting Luminous Arc Lamps

The low remuneration and character of service required demanded the adoption of the most efficient system of illumination, in order to avoid financial loss to the contractor.

The luminous arc system, with mercury rectifiers and constant current transformers, was selected, and there are at present 1637 General Electric 4 ampere magnetite arc lamps in operation, with 129 additional lights in process of erection.

Thus, the results of one year's trial justified the City of Toledo in adding within that period nearly 400 lights to the number originally specified.

Station Equipment

The required energy is generated in 3-phase Curtis turbo-generators wound for 4000 volts, Y connected.

Thirty-seven constant current 25 cycle 50 light transformers, wound for 2200 volts primary were installed, together with a corresponding number of mercury arc rectifiers and switchboard panels.

Thirty-four of these rectifiers are of the air-cooled type, the blast being supplied by either of two fans, driven by 12 h.p., 25 cycle induction motors, each of which has ample capacity for the entire 34 sets.

Recently, three sets with oil-cooled rectifiers have been added to the original installation.

Each circuit panel supports one rectifier, with adjustable blast gate, ammeter, excitation switch, primary, secondary, short circuiting plugs, bus transfer plugs, and tube tilting handle.

A totalizing panel located in the center of the arc switchboard supports three indicating wattmeters, three recording wattmeters, and two triple pole, double throw fused switches, each of these switches controlling a blower motor.

A three phase 4-wire 4000 volt bus, controlled by a motor operated oil switch, traverses the entire length of the arc switchboard behind the sub-bases. The transformers are so connected between the neutral and outer buses as to closely balance the system.

The transformers stand in two parallel rows on the engine room floor directly below the switchboard gallery, and their primary and secondary leads rise directly from the transformer terminals to the rear of the panels overhead.

In case of necessity, it is possible to supply power for the luminous arc lights by inverting either of the two 1000 kw. 25 cycle rotary converters, normally used to convert alternating current into direct current for operating the street railway.

Lines

All lines leave the power house in multiple conductor lead covered cables with $\frac{7}{32}$ in. paper insulation on each conductor. After traversing the underground district in vitrified tile, or cement lined iron duct, the circuits continue overhead on ordinary construction with double petticoat glass insulators.

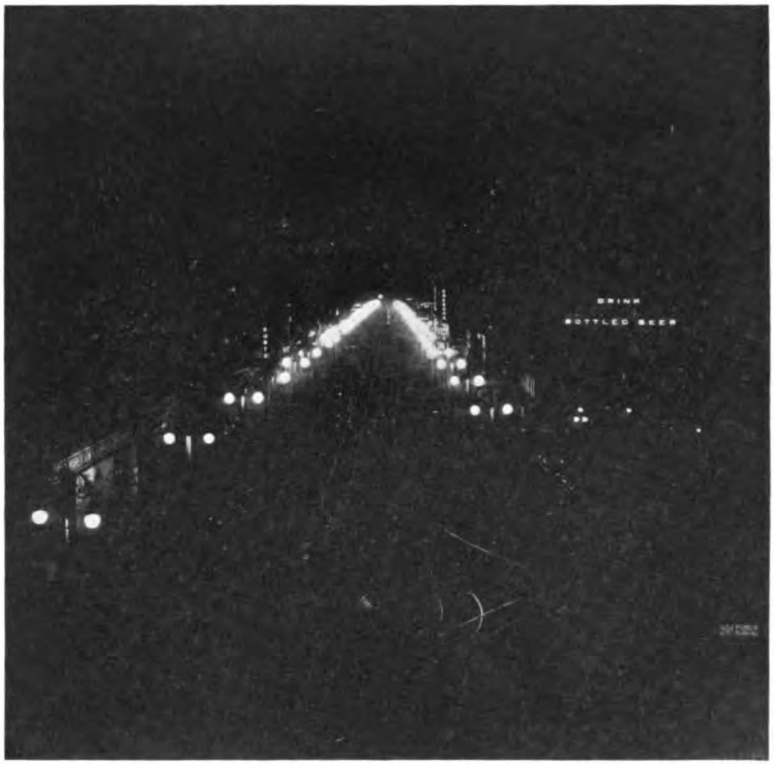


Fig. 2. Lighting of Summit Street, Toledo by Luminous Arc Lamps

No unusual line troubles have occurred, either on the aerial, underground, or submarine lines, although surges coincident with tube flashings have occasionally punctured temporary wiring between transformer secondaries and rectifiers.

Lamps

The lamps are distributed throughout the city at an average distance of 600 feet apart, and are generally hung over the center of street intersections, at a height of approximately 25 ft., by means of suspension wires, and are lowered for trimming.

The first lamps were started during stormy winter weather, and some difficulties were encountered due to high winds rupturing the arcs. Upper electrodes of ¾ in. diameter were in use, but these tended to oxidize, thus reducing the diameter, and resulting in sticking or welding of electrodes.

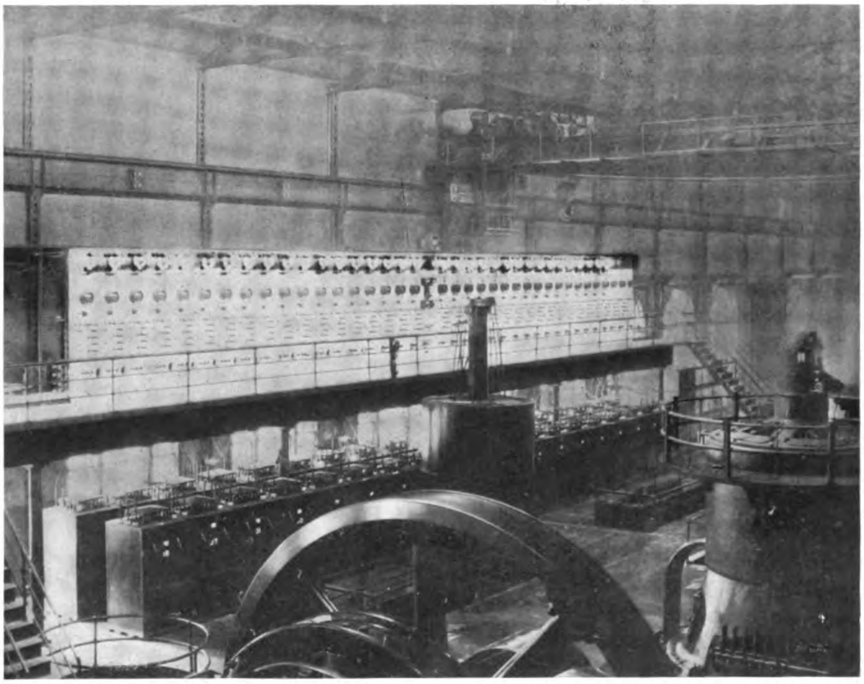


Fig. 3. Interior of Power Station of the Toledo Railway and Light Company (Daylight View)

These difficulties have been satisfactorily remedied in the later type of lamps by securing wind proof contact between globes and canopies, and by the use of upper electrodes of large diameter.

The life of the lower electrode has been increased from approximately 110 hours to over 160 hours, and it is expected that the upper electrode will last fully a year.

The luminous arc lamps in operation average from 320 to 324 watts per lamp, including line losses, as measured at the direct current circuit terminals. The watts at the circuit terminals for the alternating current 7½ ampere lamp averaged 525, showing an approximate reduction of 38 per cent. in energy per light supplied to the circuit.

The satisfaction afforded by the illumination from the new light is well illustrated by a recent incident, when it became necessary to substitute without notice the original 7½ ampere enclosed alternating current lamps in place of the luminous arc lamps, owing to the breakage, by a falling bridge span, of six arc circuits supplying some 300 lamps in East Toledo. Vigorous protests to the City Council from residents and merchants of East Toledo clearly expressed the public opinion as to which type of lamp gives the best illumination.

Gazing directly at the luminous arc, there is discernible to the trained eye a slight frequency flicker, which is imperceptible in the general illumination.

Mercury Rectifiers

The doubtful element of this system has generally been considered to be the rectifier tube life, and many inquiries regarding the luminous arc system have been aimed at the rectifier. The following data is therefore given in order to show the results in a specific case.

The manufacturer's guaranteed average life for the air cooled 50 light tubes was 400 hours operation.

Total number of tubes tried	93
Tubes failing to start	6
Tubes failing under 400 hours life	33
Tubes exceeding 400 hours life	49
Average life of these 49 to Mar. 1, 1908,	1445 hrs.
Tubes operating Mar. 1, and exceeding guaranteed life	25
Average life of these 25	1594 hrs.
Tubes exceeding 400 hrs. life and failing prior to Mar. 1, 1908	24
Average life of these tubes	1290 hrs.
Average life of 93 tubes, including failures to Mar. 1, 1908	793 hrs.
Maximum life observed to March 1,	2697 hrs.

The above record includes both oil cooled and air cooled tubes, but sufficient time has not elapsed since installing the oil cooled type to definitely establish a preference. There are, however, reasons for expecting still greater life.

Efficiency and Power Factor

In response to numerous inquiries, tests have been made of the efficiency, the power factor, and the power required to supply the air blast. These tests closely confirm the makers' guarantees. The results follow:

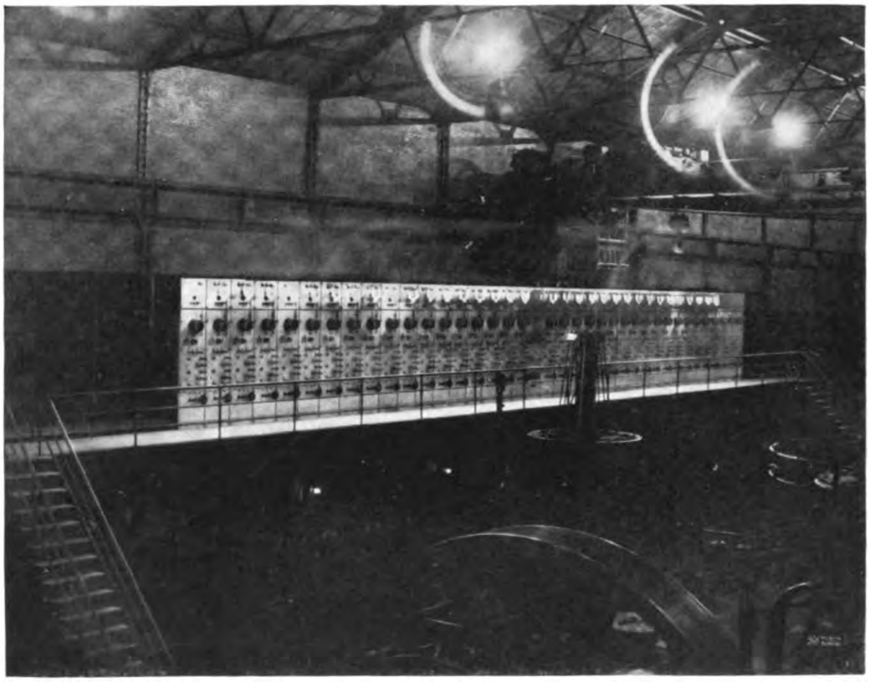


Fig. 4. Interior of Power Station by Night

Transformer on 100% Tap

	LOAD		A.C. INPUT—25 CYCLE				%-P.F.	D.C. OUTPUT			% Effic'y.
	Lamps	%-full load	Amp.	Volts	K.V.A.	Kw.		Amp.	Volts	Kw.	
a.	50	100	13.74	2308	31.70	17.55	55.4	4.04	3899	15.75	89.8
b.	37	74	13.70	2303	31.55	14.17	45.0	4.13	2892	11.94	84.3

Transformer on 80% Tap

	LOAD		A.C. INPUT—25 CYCLE				%-P.F.	D.C. OUTPUT			% Effic'y
	Lamps	%-full load	Amp.	Volts	K.V.A.	Kw.		Amp.	Volts	Kw.	
c.	37	92.5	10.01	2294	22.96	13.59	59.3	4.17	2877	12.00	88.4
d.	25	62.5	9.29	2305	21.43	10.09	47.1	4.12	1952	8.04	79.7

	a	b	c	d
Volts per lamp D.C. (line losses included)	80.0	78.2	77.8	78.1
Watts per lamp D.C. (line losses included)	315.0	323.0	324.0	321.0
Watts per lamp A.C. (line losses included)	351.0	383.0	367.0	403.0

The efficiency indicated above is the ratio of the D.C. output to the circuit to the A.C. input to the constant current transformer, and includes all losses in the transformers, reactances, rectifier, and switchboard wiring and connections. All instruments were calibrated before and after the tests.

The efficiency and power factor readings are in each case averages of ten separate tests, which showed practically no variation from each other.

The primary A.C. voltage during the tests was about 5 per cent. above rated transformer voltage, which fact accounts for the low power factor.

During each test the circuits were patrolled to insure that the full number of lamps specified were actually burning.

The values of the A.C. input to the transformer under test were closely confirmed by both the indicating and the recording wattmeters on the totalizing panel, which gave averages for the entire installation; therefore these values are not open to criticism as representing special conditions unattainable in normal operation.

Power for Air Blast

The following figures show the input to the blower motor with various numbers of blast gates opened.

Power for Air Blast. (Blower Motor Input)

No. Blast Ports Open	Kw. Input	Average Kw. per Blast
0 (Fan running light)	3.37	0.
10 (Fan running light)	4.65	0.47
20 (Fan running light)	6.08	0.30
33 (Fan running light)	6.98	0.21

An important factor in the life and operation of mercury rectifier tubes is the temperature range to which they are subjected, and unsatisfactory results from tubes of moderate voltage could perhaps frequently be attributed to improper temperature conditions. The blast temperature can not readily be regulated in all seasons and localities, and therein may lie a strong inherent advantage of the oil cooled type over the air blast type.

Display Street Lighting

The satisfactory results obtained in general from the introduction of the luminous arc lamp system in Toledo, early led to a demand for special illumination of Summit Street, one of the principal business throughfares, which includes much of the shopping district.

On each side of this street, for approximately one and one-quarter miles, ornamental iron poles, each supporting two luminous arc lamps, were erected at intervals of 80 feet. The result is perhaps the best illuminated street in America, according to the opinions of various illuminating experts.

One-half of the cost of this display lighting is borne by the City, and the other half by the merchants and property owners.

The effect of this lighting in attracting business from adjacent streets, which lack the brilliancy of Summit Street, has aroused other merchants and property owners to activity, and an installation duplicating that of Summit Street is now in process of erection on Superior Street.

Other business streets are planning similar extensions, and it may be predicted that at an early date the entire business district of Toledo will be brilliantly illuminated with an economical and harmonious system, free from the circus effects which so often offend good taste.

MILL TYPE MOTORS

By M. A. Whiting

Power and Mining Department, General Electric Company

Operating Conditions

The power required in a steel plant is much greater than that required in the largest manufacturing plant of any other industry. In addition to the main rolls, there is required a large number of auxiliary machines for handling the raw materials and the product at various stages in the train of operations. In most cases, several of these machines are handled simultaneously by one operator located at a considerable distance. For this reason, and because the distribution of electric current through a large plant is much simpler than the distribution of steam, the tendency is to use motor drive throughout.

With the exception of bloom shears and manipulators, which are generally hydraulically operated, the various classes of auxiliary machinery can be electrically driven with considerable advantage. The more important of these auxiliaries are: ore unloaders (including car dumpers), ore bridges, furnace hoists, charging machines for open hearth and reheating furnaces, cranes, screw downs for adjusting the main rolls, tilting tables, transfer tables, cambering rolls, and pull-ups for handling the rolled product to and from the hot beds. Plate bending rolls, and very small main rolls for rods and small bars may also be classed with the machines just enumerated.

These applications constitute the severest service for which the electric motor has ever been used. Motors in this class of service must meet the conditions of intermittent service with very large momentary overloads, abnormally rapid acceleration, and reversal at full speed with consequent heavy shocks.

As a rule, motors in mill service must be totally enclosed as a protection against dirt and scale, and must operate with very high surrounding temperatures. In general, the mills will run twenty-four hours a day, six or seven days a week, thus allowing very scant time at infrequent intervals in which to make repairs and replacements. In almost every case continuity of operation is of prime importance; for example, the disabling of a 50 or 75 h.p. motor on a tilting table may shut down a blooming mill, rail mill, or structural mill, interrupting the entire production. A motor which shows signs of trouble will invariably be kept in service until it is entirely disabled, or until the mill is shut down for other reasons. Motors in this service must therefore be as simple and as conveniently arranged as possible in order that they may be taken out and replaced, or opened up and defective parts replaced in the shortest possible time. In addition, the motors should require a minimum amount of inspection and should be as nearly fool proof as possible. The workmen, accustomed to handling heavy masses of steel, and working under pressure, so to speak, become very reckless in handling apparatus of any sort; thus, the motors are

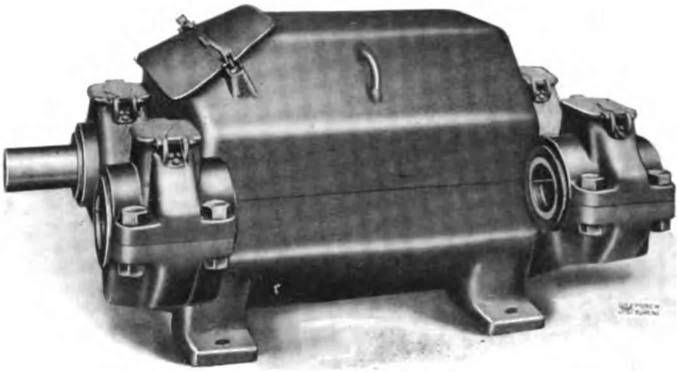


Fig. 1. MD or MI-107, 75 H.P. Motor, Back Geared

subject to a great deal of unnecessary abuse, in addition to the severe handling which is made inevitable by the requirements of the service.

The severe electrical and mechancal requirements, as outlined above, render the ordinary types of motors, including railway motors, entirely unsuitable for this work. Railway motors have been used to some extent in steel mills in spite of various disadvantages. Their shafts and bearings are not heavy enough, however, and in the larger sizes the frames are not split. The motors are entirely too compact, and commutators cannot be made large enough for satisfactory operation at 220 volts.

General Characteristics of Design

To meet the severe conditions of steel mill service, the General Electric Co. has developed the mill type motors for both direct current and alternating current. In the design of these motors the chief consideration has been a simple and extremely strong mechanical construction. The direct current machines, known as MD motors, are of the series type and are standard for 220 volts, but can be furnished for 550 volts. The alternating current machines, known as MI motors, are form M induction motors built for 25 cycles, and for 220 and 440 volts. The MD and MI motors are built in corresponding sizes which have the same horse-power ratings, ranging from 3 to 150 h.p. The corresponding sizes of the two lines of motors have the same outline and foundation dimensions. Shafts, bearing linings, frames, countershafts and various minor parts of these two lines of motors are similar, and in some cases identical. The frames are octagonal in shape and are split horizontally, the two halves of a frame being held in alignment by dowel pins, and bolted together by four heavy rough bolts with square heads, lock washers and hexagonal nuts. The corners of the bolt heads do not swing clear of the frame, this construction making it unnecessary to use two wrenches. Four heavy feet are provided at the corners of the frame, each foot being drilled for one large holding down bolt.

The armatures have been made small in diameter so that when reversing rapidly they will not require excessive power for acceleration.

Large openings are provided at the commutator or collector end to allow easy access to the brush rigging. The covers are of malleable iron and are held in place by a hinged lock bolt. The housings for the armature bearings are part of the frame and are liberally designed, no effort being made to crowd them inside the frame. Bearing linings are cast iron, babbitted, and offer a long bearing surface. A shoulder at the end of the lining nearer the armature bears against a machined vertical surface on the lower housing, the armature end thrust being thus transmitted from a shoulder on the shaft, directly through the shoulder of the bearing lining to the lower half of the frame. The bearing linings are split, the two halves being bolted together, thus permitting the use of solid oil rings. A forged bail is cast in the upper half of each lining by means of which the armature may be handled. The lower lining is provided with a projection on each side, which rests against the upper bearing housing and prevents the lining from rotating, the use of dowel pins being thus avoided.

The armature bearings are supplied for waste lubrication, or for oil ring lubrication with two rings per bearing. To change from ring to waste lubrication, it is simply necessary to change the linings. Oil grooves and deflectors are provided to prevent leakage of oil at any point.

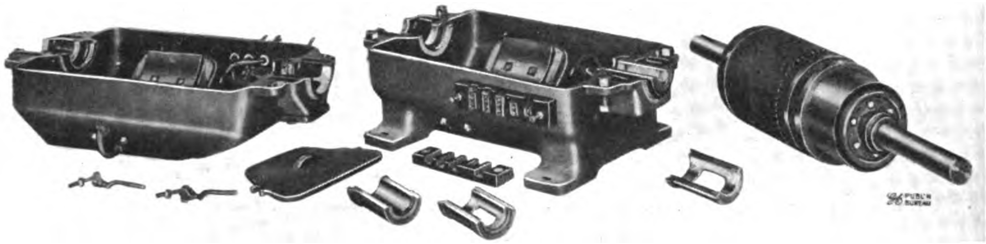


Fig. 2. Exploded View of MD-106, 50 H.P. Motor

Countershaft bearing brackets are a part of the lower half of the frame, while the caps for these bearing brackets are held down by two rough bolts at diagonal corners, and are lined up by a tongue and groove. The linings are split, and of the same general design as the armature bearing linings, with the exception that the two halves are not bolted together, and the bails are omitted. Countershaft bearings are designed for waste lubrication.

The shafts are extra heavy, being designed for an ample factor of safety against maximum combined stresses at 100 per cent. overload. The pinions are made of the best grade of hammered steel, and the gears of cast steel, the width of face being considerably greater than for standard railway practice. Tooth stresses are computed on a basis of 100 per cent. overload. Split or solid gears are furnished.

MD Motors

The pole pieces are laminated, according to standard practice. Each pole piece is held in place by two square headed bolts, which prevent improper alignment of the pole piece. The field coils are wound with flat strip copper, are insulated between turns with asbestos, and covered with sheet mica and asbestos tape, well filled with insulating varnish.

The armature core is built up of soft steel laminations keyed to a spider according to standard practice. A bar winding is used in open slots, the bars being held in place by binding wires recessed below the core surface.

The commutator shell is carried on an extension of the armature spider, allowing the shaft to be removed without disturbing the connections. The segments have solid ears, the ends of the armature bars extending directly into the slots in these ears, thus eliminating the commutator leads.

The brush rigging is of a simple and substantial construction, the body being of cast iron and the brush boxes of brass. A heavy coiled spring of phosphor bronze is used, which has no adjusting lever or other small parts to get out of order. Brush holder studs are screwed into the frame, no provision being made for shifting the brushes, as the motors, being reversible, are designed to operate with brushes at the neutral point. The largest motor, which is a six pole machine, has four studs, one of which is in the lower half of the frame, the lead for this stud being brought to the outside. Each of the other motors has only two studs, both in the upper half, thus simplifying the connections and rendering inspection a very easy matter. All connections between the two halves of the motor are brought to the outside. No connection board

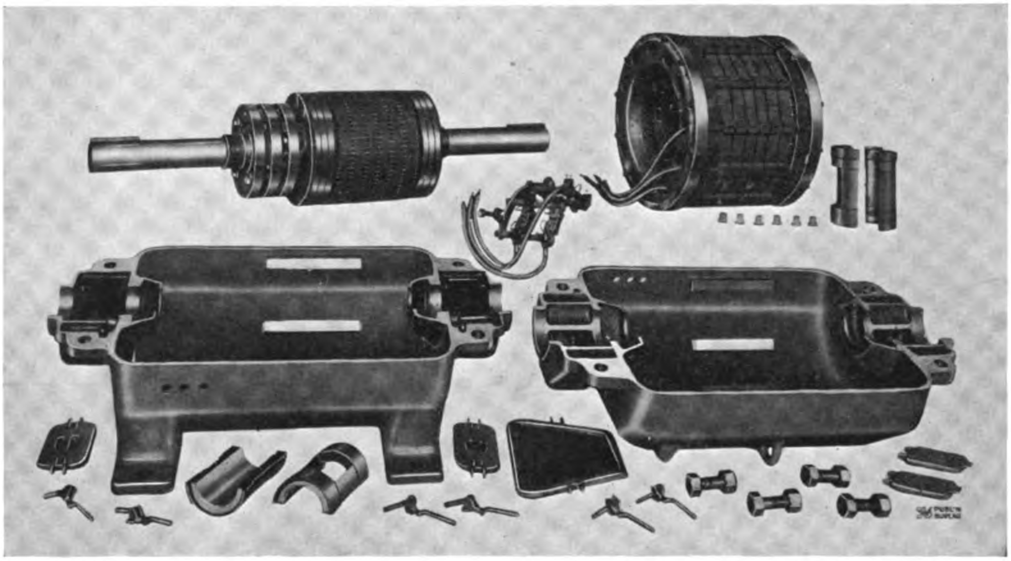


Fig. 3. Exploded View of MI-107, 75 H.P. Motor

is used, as the leads are provided with a simple form of coupling over which an insulating sleeve is slipped.

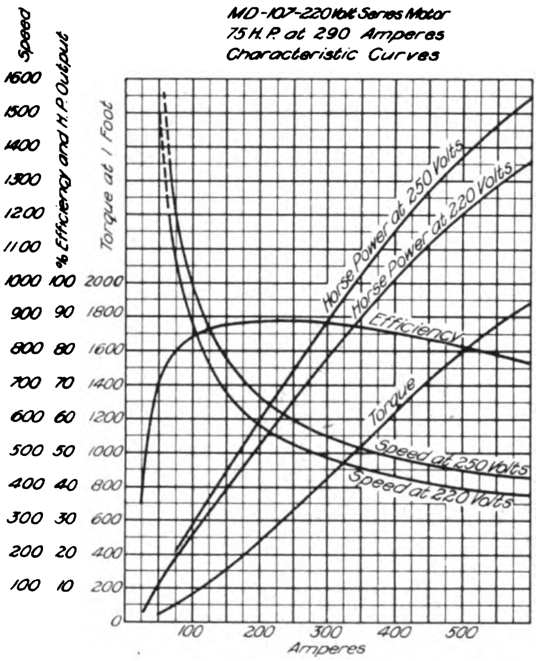


Fig. 4. Characteristic Curves of MD-107, 75 H.P. Series Motor

The MD motors are standard for 220 volts, with series field. Compound windings are usually 20 to 25 per cent. shunt, limiting the free running speed to about twice full load speed. Commutating poles are used on the four largest sizes, insuring black commutation at excessive overloads.

The efficiencies of these motors are important, not with respect to power consumption, but with respect to heating, and the efficiencies have, therefore, been made as high as is consistent with the severe mechanical requirements. The MD motors have efficiencies about three per cent. higher than those of the corresponding sizes of railway motors, the value for the larger sizes being about 90 per cent. at full load.

These motors will operate totally enclosed at rated load for one hour, with temperature rises of 65 to 75° C. by thermometer. The limit of commutation has never been reached on any of these machines, commutation being black at 100 per cent. overload, and only very slight sparking occurring at 200 to 300 per cent. overload.

MI Motors

As mentioned above, the MI motors have the same outline and foundation dimensions as the MD motors of corresponding sizes; the two types are, therefore, interchangeable. The MI motor has a split box frame from which the stator can be removed, this feature involving a radical departure from standard practice with respect to mechanical design of induction motors.

The stator is made up as a complete and separate unit. The punchings are assembled on twelve steel studs passing through ears on the outer circumference. By means of these studs the punchings are clamped rigidly between cast iron end flanges. Open slots are used, and liberal air ducts are provided for ventilation.

Coils are form wound and moulded to exact size before assembling on the stator, this arrangement rendering the coils interchangeable, and facilitating repairs. The principal insulation is placed on the coil, although ample slot armor is also provided. The coils are held in place by heavy wedges, and supporting rings bolted to the end flanges protect the coil ends. The completed stator is therefore proof against careless handling.

When the stator is let down into the frame, the ear at the bottom of the stator fits closely between two machined ribs on the frame, thus preventing the torque of the motor from revolving the stator. Each half of the frame contains several such ribs, bored out to the exact diameter of the outer surface of the stator, and when the two halves of the frame are bolted together the stator is brought into alignment and held rigidly in place.

The rotor spider is extra heavy, the punchings being held in place by double dovetails, and, in addition, by steel pins driven through reamed holes near the inner circumference. The end flanges are pressed on the spider and held by lengthwise and crosswise keys. The rotor is of the form M type, polar wound, a bar winding being used in partially closed slots.

In view of the severe service for which these motors are designed, the air gap has been made much larger than standard practice, being two and one-half to three times that of the usual type of induction motor with the same diameter of rotor.

The collector rings are of the open form, large in diameter, and of a heavy, rigid construction. They have fans cast on them, which help to maintain a circulation of air inside the motor. The collector rings are mounted on a shell which fits on an extension of the rotor spider, making it possible to remove the shaft without disturbing the collector. The well-known clock spring type of brush holder is used with heavy cast brass brush boxes and carbon brushes. Each of the three brush holders is supported at both ends, four studs in all being used, which are carried by a yoke bolted to the upper half of the frame. The arrangement of the brush rigging, and the large size of the upper hand hole cover make the brush holders easily accessible for inspection or for replacement of brushes. The rotor leads are brought out through the upper half of the frame, and the stator leads through the lower half. In taking the motor apart it is therefore unnecessary to break any connections inside of the motor.

The MI motors are wound for 220 or 440 volts, and as previously mentioned, they are form M, the control being accomplished by means of resistance in the rotor or secondary circuit. In the layout of these motors, the chief considerations were superior mechanical construction and ease of repairs and replacement. Notwithstanding the severe mechanical requirements of the design, high efficiencies have been obtained, equal in most cases to those of the usual type of form M motors, the average in the larger sizes being about 90 per cent. The power factors of the MI motors are lower than those for standard motors; this is a necessary result of the increased air gap, and need not be considered a disadvantage in this type of machine. In cases where a high power factor is essential, the operating conditions are not, as a rule, so severe as to require machines of the extremely rigid design of the MI motors, and motors of the usual type can therefore be used. It should be noted that the power factors are highest between full load and 100 per cent. overload. As these motors will ordinarily operate at large momentary overloads, the average power factors will be better than is apparent from the first glance at the curves. These motors have a maximum torque, ranging in the various sizes between 240 and 267 per cent. of full load torque.

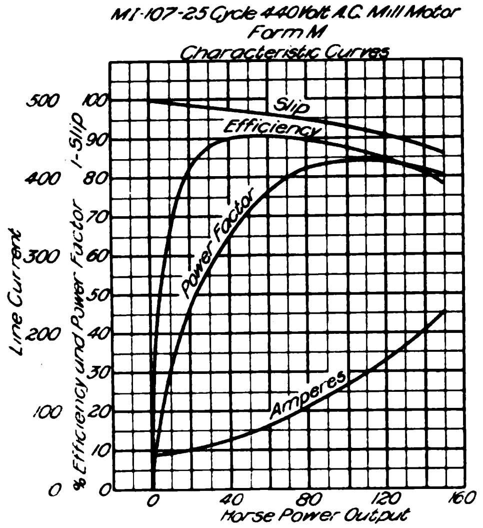


Fig 5

Characteristic Curves of MI-107, 75 H.P. Motor

The current and torque during acceleration depend to a large extent upon the control equipment used; this point will therefore be taken up in the discussion of control.

When totally enclosed, the MI motors will operate at rated load for one hour with temperature rises, by thermometer, of 65 to 75 degrees C.

Control

Either drum or type M control may be used with the mill type motors. For the smaller sizes, drum control will in many cases prove satisfactory, while for the large motors, drum controllers should not be used except for infrequent service. For heavy duty the type M control system should be used, as it is more reliable, will handle heavier currents, and involves much less repairs and depreciation. Since the master controllers are small, several can be installed within easy reach of one operator; also, several motors can be operated as a unit from one master controller.

Type M systems in general may be divided into three classes; namely, hand, time limit, and current limit control. In a hand control system the successive resistances can be cut out either at intervals or simultaneously, at the will of the operator. With a time limit system, although the operator may throw the controller handle instantly to the full running position, each resistance step must remain in circuit a predetermined time before being cut out. With a current limit system, the current on each point must fall to a certain value, irrespective of the elapsed time, before the motor can be notched up to the next point. With either a time limit or current limit system, the master controller can be thrown instantly to the full running position, in which case the motor will accelerate at a rate subject only to the predetermined limit; or the controller may be moved up one notch at a time, thus obtaining a slower acceleration. This arrangement is usually spoken of as a combined hand and automatic control.

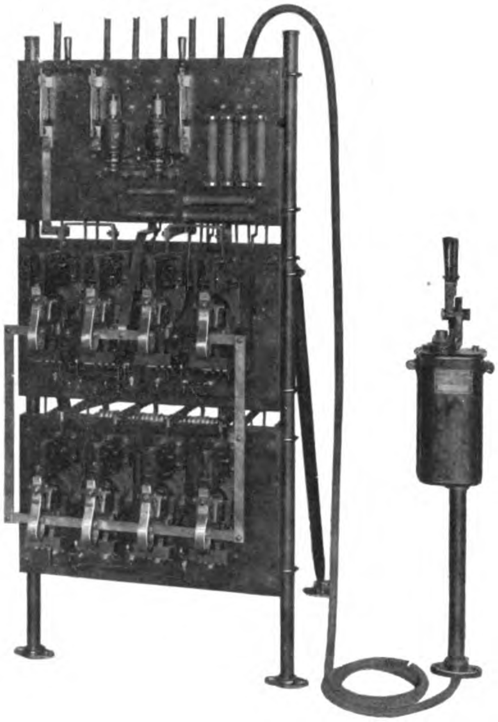


Fig. 6. Type M Control Equipment for Mill Motors

Most of the apparatus is similar for the three systems, the connections and the limit device being the principal points of difference. As current limit equipments are preferred almost without exception for steel mill work, the discussion will be confined to this system. The motor circuit is closed and the resistances cut out by electrically operated switches known as contactors, operated by a circuit which is energized by the power supply and controlled by a small master controller. The control circuit passes through electrical interlocks on the contactors, and through a current limit relay in the main circuit. The interlocks consist of make and break contacts in the control circuit, and are attached to and operated by their respective contactors.

The connections through the relay and interlocks are arranged so as to accomplish several results. First, the line contactors are interlocked so that it is impossible for both pairs of contactors to be closed at the same time, which operation would short circuit the line. Second, the contactors which cut out the resistance are interlocked with the relay in such a manner that a contactor cannot be closed (cutting out a section of resistance) until the load current falls to a certain predetermined value. But when closed these contactors will remain so, independently of the operation of the relay. Third, adjacent contactors are interlocked with one another so that they must close in succession and not simultaneously.

The master controller commonly used has several segments, corresponding to the various steps, enabling the operator to start up slowly, notching up by hand. Or, if desired, the controller may be thrown instantly to the full running position, allowing the motor to accelerate automatically at a rate limited only by the current limit relay. With this

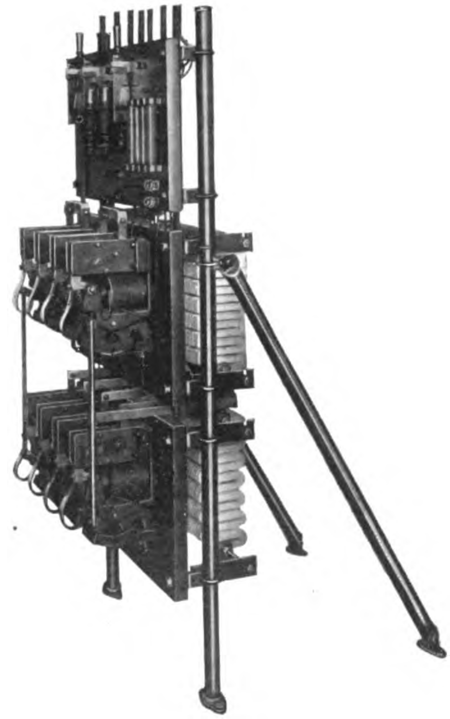


Fig. 7. Type M Control Equipment, Side View

form of master controller the motor can be operated at reduced speeds, either by notching up to the required point from stand still, or by notching down from full speed.

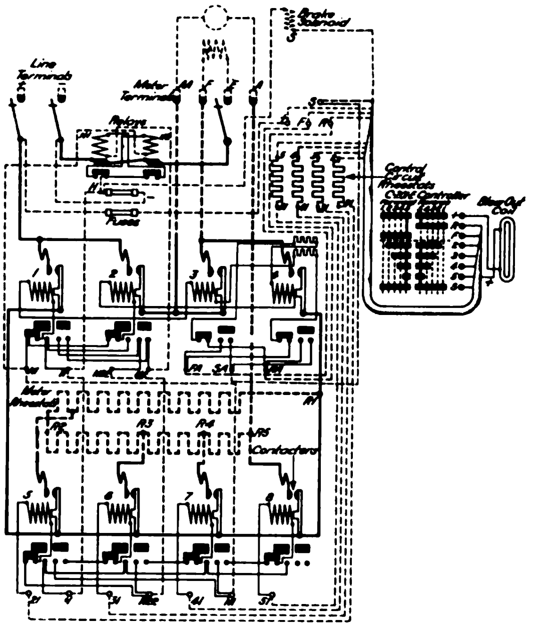


Fig. 8. Connections of Type M Control for MD Motors

Fig. 8 shows the connections of a direct current equipment with five points forward and reverse, used for operating a series motor. For a motor with a small shunt winding the control is similar, the shunt field being carried through the master controller. In this way the shunt field is opened, discharging into a resistance, every time the controller is thrown to the off position. It is thus impossible for a careless operator to leave the shunt field on, when the motor is shut down. When conditions render it necessary, a shunt field relay may be used, its function being to prevent the operation of the motor if the shunt field is broken.

Fig. 9 shows the connections of an alternating current equipment—seven points forward and reverse. The wiring of contactor coils, interlocks and relays is practically the same for the direct current and alternating current equipments.

The proper number of points in a control equipment depends upon several considerations. To obtain considerable refinement with respect to uniformity of acceleration and reduction of current peaks and motor losses, a larger number of points should be used than would otherwise be required. In the case of the type M equipments, however, a large number of points means a very expensive and complicated equipment, with a consequent increase in repairs and depreciation. Furthermore, in service requiring an extremely rapid acceleration, if a large number of points is used the contactors will not close rapidly enough. In mill service, therefore, the tendency is always toward a very few points. With the MD motors in heavy reversing service, five points with current limit are sufficient. With the MI motors the control should, as a rule, have seven points, which, in connection with a current limit, will give a satisfactory acceleration over a wide range of operating conditions.

In installations of MI motors for heavy service there is an additional reason, not mentioned in the foregoing, for using type M control. If an induction motor operated by a drum controller is started by throwing the controller handle instantly to the full running position, the motor will be thrown on the last, or full running point, before it has time to speed up, and a very low torque will therefore be obtained, with an excessive current input. A still worse condition will be obtained if the motor is suddenly reversed at full speed. A time limit device offers only a partial remedy, as it notches the motor up to full running position in a certain number of seconds, independently of the load. A time limit, therefore, will not positively prevent

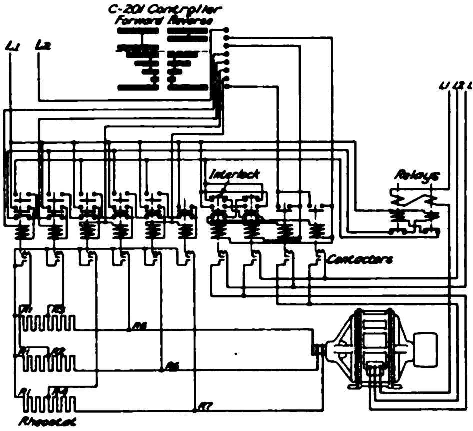


Fig. 9. Connections of Type M Control for MI Motors

the motor from reaching the last control point at too low a speed. In order to make it impossible to stall the motor by improper acceleration, and in order to secure the required torque with a minimum current input, it is necessary to use a type M equipment with current limit.

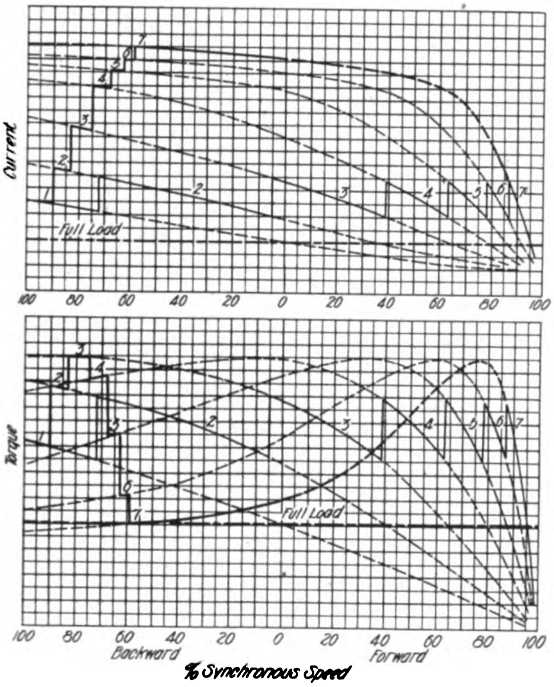


Fig. 10. Curves Showing Disadvantage of Drum Control with Induction Motors in Reversing Service

Fig. 10 illustrates, in a general way, the difference between a current limit acceleration and the acceleration obtained under unfavorable conditions with a drum controller. The heavy lines represent torque and current obtained by suddenly reversing a 75 h.p. MI motor at full speed by means of a drum controller, and the light solid lines represent the current and torque obtained by a type M current limit acceleration, the controller handle in each case being thrown instantly from full forward position to full reverse. With the drum controller the torque increases to a maximum on the third point and decreases on the following points, coming down approximately to full load torque on the full running position. Although the torque beyond the third point decreases, the current increases at every step, reaching a maximum of 400 per cent. of full load current. If the friction load is not too great, the motor, after coming to rest, will accelerate slowly (the torque being low, as shown by the heavy dotted curve), until the speed approaches the value corresponding to the peak of the torque curve. In the meantime a tremendous current will be taken. If the friction load is very large, however, the motor will not have sufficient torque on the last point to come up to speed, and will therefore be stalled.

In contrast to this cycle of operation which may be obtained with a drum controller, that obtained with a current limit acceleration is shown by the light solid lines in the same set of curves (Fig. 10). The torque varies between uniform maximum and minimum values throughout the reversal, a high average being maintained. The current also varies between uniform maximum and minimum values, the maximum current being less than half that obtained in the sudden reversal with the drum controller.

Fig. 11 gives a typical set of torque and current curves for an MI-107-75 h.p. motor with a seven point current limit control. These curves are laid out to cover the entire range from full speed reverse to full speed forward. The torque and current curves shown represent the proportioning of control resistance, which is suitable over the widest range of service conditions. The curves in Fig. 11 represent the most suitable control for reversing service, with average torque ranging from 150 to 225 per cent. full load torque; or for non-reversing service, with average torque ranging from 80 to 150 per cent. full load torque. If for reversing or non-reversing service, a greater torque is desired than the values given above, the same equipment will still prove satisfactory. If the acceleration is very rapid, however, the maximum torque of the motor will not be reached until the motor has slowed down considerably. If less torque is desired than that given above, the torque and current on the first point will be much higher than on the following points. However, unless considerable refinement is desired, it will be unnecessary, even in extreme cases, to depart from the standard equipment. Adjustment for a high or low torque is made by setting the current limit relay for a high or low current limit, the relay being adjustable over a wide range.

In Fig. 11 the light solid lines represent current and torque, with a current limit of

150 amperes. On the first step the torque and current are low; on the second and following steps the current varies between 225 and 150 amperes, and the torque varies between 1800 and 1320. The mean square current over the entire acceleration is 28,700, and the mean torque is 1550. If the current limit is raised to 200 amperes, the acceleration will be as shown by the heavy lines, the maximum current and torque being reached on the third and succeeding points. The current then varies between 285 and 200 amperes, and the torque between 1670 and 2050; the mean square current over the entire acceleration being 53,500, and the mean torque 1800. The maximum current therefore increases 26 per cent. for a 16 per cent. increase in torque. Making allowance for the less time to reverse at the higher torque, the heating due to copper losses increases 60 per cent. for a 16 per cent. increase in torque. If the current limit is raised to a still higher value, the copper losses and maximum current will, as before, increase more rapidly than the torque. As a rule, therefore, it will be found inadvisable to adjust the current limit to accelerate the motor at maximum torque. If the maximum torque is required, it can be obtained by setting the current limit at 275 amperes (not shown in Fig. 11), at which adjustment the motor will accelerate entirely on the peaks of the torque curves. If the motor is reversing a very heavy load, it will be notched up rapidly to the third point, where maximum torque is obtained. From the third point to the full running point, the mean torque is 2075, which is only 1 per cent. below the maximum torque of the motor. This value of mean torque represents the extreme limit of performance of the motor, and can be closely approached only when the acceleration is slow compared with the time required for the control equipment to operate.

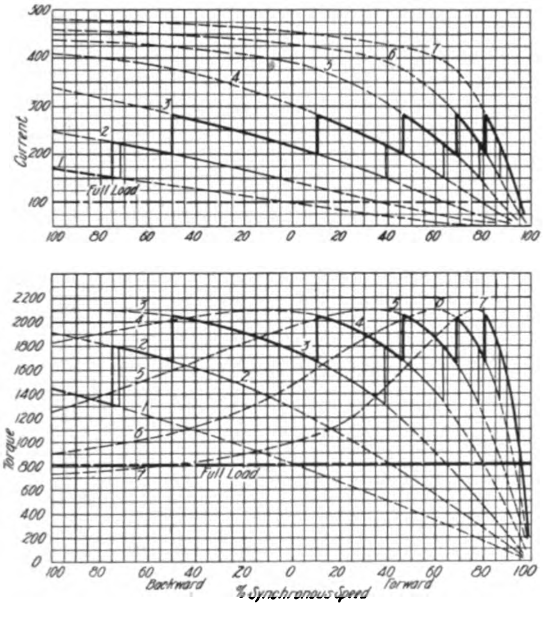


Fig. 11. Torque and Current Curves

The torque and current curves of the other MI motors are similar to those of the MI-107 shown in Fig. 11. In applying current limit control to these motors, the limiting conditions and operating characteristics are the same as those briefly outlined in the foregoing discussion.

Applications

The large majority of applications of the mill type motors will always be in and about steel mills, where the tendency is to use mill type motors throughout. It should be borne in mind that these motors were developed primarily to meet steel mill conditions, and therefore do not offer any particular advantage in general applications. In classes of work where any of the common types of motors have proved entirely satisfactory, the introduction of mill type motors is unwarranted. With the exception of bending and straightening rolls, and possibly some forms of shears, there is probably no class of ordinary machine tools to which the mill motors can be advantageously applied.

There are, however, certain other classes of work in which severe service conditions may make it advisable to use mill type motors. Gas plant charging machines and coke oven larries involve much the same conditions of heat, dust and rapid reversals which are met with in steel mills. In hoist work requiring an exceptionally high rate of acceleration, an ordinary type of motor will consume too much power in its own acceleration. In this respect the mill motors, with their small armature diameters, offer a marked advantage. These motors are also particularly well adapted to the operation of dredges, shovels, and other excavating machinery, where rapid acceleration, reversals, shocks, and general abuse of equipments render the service extremely severe.

SOME SUGGESTIONS ON THE CONSTRUCTION AND ARRANGEMENT OF SMALL TRANSFORMER SUBSTATIONS

By C. M. Hackett

Power and Mining Department, General Electric Co.

At present there are few, if any, small transforming stations that may be termed representative, the tendency being, as is the case in most new applications of electric power, to utilize available space in existing buildings, or to put up temporary buildings at small cost and install the apparatus in such a manner as, in the purchaser's opinion, will answer present requirements.

The fact that these installations can be effected cheaply makes a strong appeal to the prospective customer, and this feature is, of necessity, bound to be emphasized in making the sale of apparatus. There is no reason, however, why the advantages of a good arrangement cannot be had at as low an initial cost as a poor one, and the subsequent costs of operation, repairs and changes be carried on much more economically thereby.

It may be considered a good method of procedure to let the conditions to be met determine the location of the station, if possible, as the arbitrary placing of the source of power for a plant at some place which has for its chief advantage the fact that it can be made ready with the least amount of present trouble and expense, is likely to prove annoying and costly.

The next point for consideration is naturally that of the transmission line capacity and voltage. If conditions are such that a sufficient number of power consumers can be found within a reasonable radius to warrant the power company in establishing a transforming station and building a branch line to operate at a reduced voltage, the problem for the individual consumer is much simplified and cheapened. If, however, it is necessary to tap directly to the main transmission line, which may carry many thousands of horsepower at a potential of 33,000 volts or more, the question of providing suitable controlling devices, such as lightning arresters, and oil switches of suitable rupturing capacity, becomes of so serious a nature that a transformer installation of small capacity, 500 h.p. or less, is impracticable. This is true both from the consumer's standpoint of initial cost and subsequent operation, and from that of the power company, as the latter would be unwilling to take the additional chances of interruption of service introduced by the taps to their lines, unless the amount of power consumed should be a reasonably large percentage of their output.

Transforming stations may be divided into two general classes:

1st. Those which have the control of the power distribution in the station, with the possible addition of rotating auxiliaries, such as converters or motor generator sets, and which have a diversity of service of both alternating and direct current. (Fig. 1).

2nd. Those which have control in part at the point where power is consumed, no rotating units in station, and only alternating current of one voltage in use. (Fig. 2).

Under the first class will come the stations for supplying power for manufacturing establishments, these establishments requiring various types and capacities of motor drive, with lighting and possibly electric furnace service. The consumption of power for such a plant will possibly amount to 5000 kw.

For a station of this capacity, a building should be especially constructed, as only by so doing will it be possible to meet the requirements of the installation in a practicable manner.

If possible, there should be duplicate feeders to the station, with tie buses and switches between them, and also a complete complement of lightning arresters, disconnecting switches, choke coils and oil switches, and all reasonable precautions should be taken to minimize the chances of interruption of service. For convenience in installing machinery, the station should be so located, if possible, that a spur track may be run along both sides of it, and the main floor should be about four feet above the top of these rails. It will generally be found unnecessary to provide working space, crane, etc., in the station for removing windings from transformers, as the transformers themselves can be easily taken to some convenient point in the plant where proper appliances for this work are available, thus materially reducing the size and cost of the building, besides making it possible to isolate the transformers from all other apparatus, and from each other, if desired. As the transformers are accessible only through doors opening to the outside air, this isolation is especially complete, and possesses all the advantages to be had in this method of transformer installation.

Only a small part of the building need be carried up two stories, and in this part are arranged the lightning arresters, choke coils, transfer bus and oil switches. The bus and switch arrangement may be made very simple, with open wiring and knife switches in the transfer bus; or the arrangement may be elaborated upon by enclosing the buses, and employing oil switches for sectionalizing and for connecting lines and between transformers and buses. The conditions governing each proposition should determine the extent to which this elaboration should be carried.

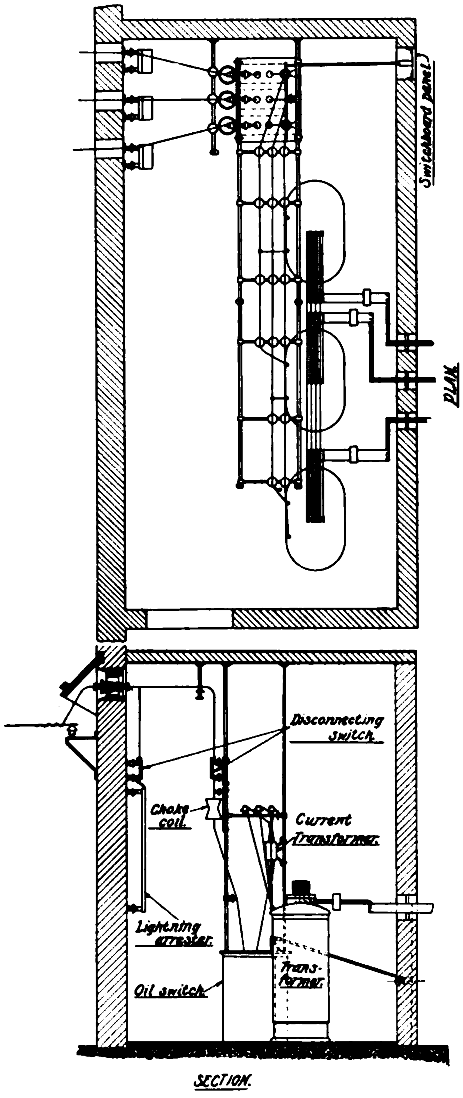
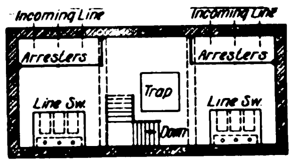


Fig. 1

The space required for lightning arresters, as well as the most practical location for them, which should provide adequate means for inspection and operation, is largely dependent on the line voltage. For low voltages (2300 to 13,000), the lightning arresters, if of the multi-gap type, may be easily placed in the same room with the switch and bus equipment. For higher voltages (33,000 and above), some special arrangement will generally be found necessary, and this will vary with the type of arrester used, and with the conditions of climate. In the warmer climates where little or no snow falls, the arresters, if of the electrolytic type, may be frequently installed on the roof of the station to good advantage, but in colder climates they should preferably be inside of the station, or under some form of shelter. It will generally be found advisable to have the horn gaps in the open air, so located as to be safe and convenient for operation and accessible for inspection. Only in cases where the available space is large, fire proof, and so arranged that it is occupied exclusively by the lightning arrester equipment, should horn gaps be placed inside of the building. If ground space is available, one of the most economical ways of installing an electrolytic type of arrester is to construct a small building near the station in which the cells can be placed, while horn gaps may be arranged upon the roof. These horn gaps may be located directly under the transmission line if the wires are of sufficient height above the ground, say forty feet or more for voltages not exceeding 60,000. If it is impracticable to have transmission lines at such an elevation, the arrester house should be placed to one side so as to give a safe clearance between horn-gaps and wires.

The shelter house for the arresters need not be more than 16 ft. in height; this should give a minimum distance of about 20 ft. between the horn gaps and the wires, if the house is built beneath the transmission lines. While not absolutely necessary, it will be preferable to have this house non-inflammable.

The operating room of the station, which contains the switchboard and such rotating auxiliaries as are required, should be well lighted by both natural and artificial light, and should have doors properly arranged for bringing in machinery, in addition to the small doors for the use of operators. The height of the room will be dependent on whether or not it is necessary to have a traveling crane, and this in turn will depend on the size and number of machines installed. If these aggregate 1000 kw. output, or more, it may be considered good economy to install a hand-power crane of sufficient capacity to handle the heaviest piece.



Plan of Line Tower

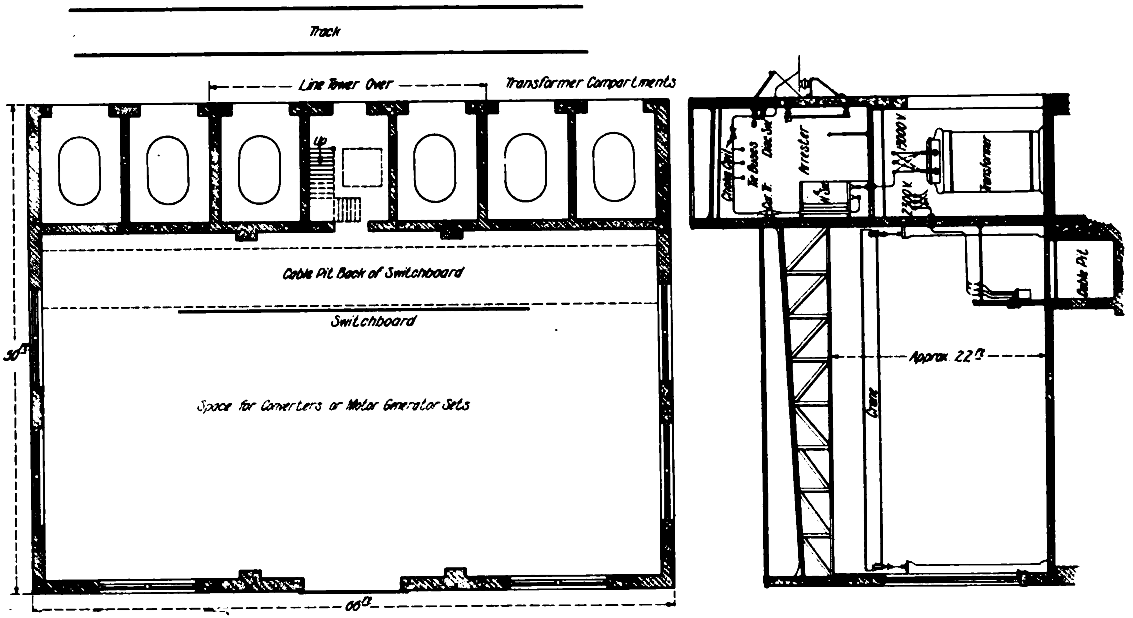


Fig. 2

In the matter of the basement, the amount of cable to be installed must be considered; and in addition, the cost of foundations under the machines; the cost of floor construction, when supported by structural steel; and the necessary excavation. The expense and advantages of this arrangement must be contrasted with those of simply filling in and placing the floor directly on the ground. Assuming that the floor of the station is 4 ft. above grade, the advantages of the basement will frequently offset the small extra expense of the steel floor supports and excavation. In case it is decided to fill in and place the floor on the fill, great care must be exercised in tamping in the filling material, or the floor will soon settle out of level, crack, and break up. In all cases, machine foundations must have their footings well below the original surface of the ground.

A cable pit should be provided below the switchboard for the proper arrangement and distribution of wires, as, in an installation of this type, the number and size of wires to be disposed of will be large enough to make it difficult to properly handle them in any other way. From this cable pit, a conduit system may be run to convenient points about the plant, thus permitting apparatus to be connected up with a minimum amount of open wiring.

Material to be used in the construction of the building should, without question, be fire-proof in every respect. That portion of the building which contains transformers, high tension switches, buses, lightning arresters, etc., should preferably be built of brick and concrete, omitting as far as possible all structural steel that might be exposed to the action of fire. It will generally be found possible to so arrange the main walls and partitions that some standard form of reinforced concrete can be used, thus eliminating all necessity for having any exposed steel construction.

A roof with a single slope, if less than 50 ft. span, is to be recommended, as nearly any type of tile or concrete construction can be used, and if the slope is not more than one foot in 20 ft., no trouble will be found from washing by storms. If the span is short, that is, not more than 25 ft., ordinary I-beams can be used to good advantage to support the roof; but if the span is longer than this, a truss construction will be found more economical. The flat roof also permits the forming of drainage slopes to leaders at the most convenient points. In cold climates, leaders should be carried down inside of the building and run to the drainage system. If suitable drainage is not available, parapet walls should be omitted and a regular cave construction used, allowing the water to drip to the ground.

In warmer climates, where other ventilation than that afforded by windows is necessary, monitors may be placed in the roof with a pivoted sash; but if a cheaper system of ventilation is needed, iron ventilators similar to the star type will give very good results.

In a station where transformers are water-cooled, the extensiveness of the piping system will depend upon whether the water supply can be had under sufficient head to operate the system without the use of pumps, and upon whether a sufficient quantity can be obtained at a cost which is not prohibitive. The ideal system is one which eliminates all pumps and cooling apparatus, and consists in simply connecting the supply header to the transformer cooling coils, and thence to the drainage system. If, however, this is not practicable, and water must be purchased at considerable expense, it will be found advisable to arrange a system with pumps and a cooling tank so that the water can be used repeatedly, supplying only enough additional water to offset the loss by evaporation. In the latter case, a tank of a size proportionate to the amount of water required in the system should be so placed as to give a natural head, forcing the water through the transformers to the drain, thence to the receiving tank, whence it can be raised by a pump to the cooling apparatus. This latter may be of simple character, the climate determining whether it can be placed in the open air, or whether it must be enclosed to prevent freezing. Unless the amount of water to be cooled is large, an ordinary pipe header, with branches from which small outlet nozzles spray water into the receiving tank, will be adequate without a tower.

In case it is impracticable to have a cooler and a tank in the upper part of the building, a sufficient amount of basement room should be provided for them, and the circulating pump may then operate directly on the header for the transformer cooling coils.

In piping for the cooling system, supply headers should be of sufficient size to permit a slow flow movement when all transformers are under normal load. Arrangements should also be made for forcing a sufficiently rapid flow through the cooling coils to flush out any sediment which may be deposited there. The system as outlined here is of the open type; that is, with a break arranged in the pipe on the discharge side of the cooling coil to enable the rate of flow and the temperature of the water to be ascertained, as well as for the convenient attaching of a hose for carrying away the sediment when the coils are flushed out. With the exception of the devices for indicating the flow and the temperature, which devices are connected in the piping circuit, the closed system may be arranged in the same manner as outlined for the open.

For the air-cooled type of transformers, a ventilating system should be arranged which will provide a volume of air sufficient to carry off the heat generated at maximum load. If conditions are such that this ventilation cannot be produced satisfactorily with natural draught, a blower should be provided, with necessary passages to the transformer compartments.

All stations that have oil insulated transformers should have some provision for filling and emptying the tanks. As this has to be done only at long periods of time, a comparatively simple outfit will suffice.

A vacuum pump, power operated if possible, that can be used to exhaust air from transformer tanks while oil is being pumped in, gives the most nearly perfect results. Owing to the difficulty of getting a sufficiently good vacuum to draw oil into the transformer to the required height, a force pump should be provided for use in conjunction with the vacuum pump. Excellent results can be obtained in this manner, only a small amount of trouble being necessary to make the connections tight on the transformer. When filling transformers for high voltage, should the weather be damp, it is good policy to pass all air which enters the barrels from which the oil is being taken, through calcium chloride to prevent the introduction of water.

To empty oil from the transformer tanks is a simple matter if the station is built with the floor well above the grade, or if a basement is provided. Pipes can then be connected to the bottom of each transformer outlet, and through these the oil can be run to barrels or a tank as desired. If, however, the transformers are not in a proper position for being emptied directly by gravity, a force pump with a short length of hose may be attached to the transformer outlet, and the oil pumped to the storage. When three or more transformers are installed in the same room where the floor is on the ground at grade, they can be piped to a common header buried beneath the floor, and through this header oil can be run to a pit large enough to hold a barrel of the size commonly used in shipping transil oil. Above this pit, supports for a fall should be arranged for handling the barrels.

For the second class of transformer substations, the remarks concerning the power line, arresters and high tension switching system of the first class will apply with some modifications, these modifications being along the lines suggested by the smaller capacity of the station. This second class of substations naturally includes those which must be operated from a line of small capacity, whether it be from a small generating plant or from a branch of a line of large capacity, thus making the controlling features of the arrangement much more simple and direct.

The same care should be used in regard to all wiring and connections as in the case of the more complicated installations, such as the spacing of high tension leads, distance to ground, insulators and insulating, line entrances and anchorages, and the location of lightning arresters.

The station may consist of a small building erected expressly for the purpose, or of a room partitioned off in an existing building. If the latter is the case, or if the whole of an existing building is to be used, the manner of bringing in feeders will be likely to have some influence on the arrangement of the apparatus. Where the walls are of a sufficient height to permit the lines being brought through so that it is possible to locate disconnecting switches, lightning arresters, choke coils, etc., high enough to be clear of other apparatus, the arrangement should be simple, straightforward and compact; but if the building is low, so that a tower or dormer must be used in order to get the entering lines far enough above the ground to be safe, there will generally be complications in wiring which will make it necessary to occupy considerably more floor space in order to render the installation safe and convenient. Since a single line will probably be considered sufficient for an equipment of this capacity, a hand-operated oil switch, with automatic trip for opening the circuit in case of emergency, will be satisfactory. From this, connections may be made directly to the transformers, all wiring being open and supported by porcelain insulators mounted on the walls or pipe framework. In case there are two or more banks of transformers, the introduction of additional oil switches and buses may be found necessary.

If the entire output of the transformer station is required for a single service, such as an electric furnace, the secondary connection from the transformers should be run directly to the carbon holders of the furnace, as this method requires only the simplest arrangements in the way of supports, and for control.

On the other hand, if power must be distributed to a number of points, and if it is important that the chances of interruption be reduced to a minimum, a low tension bus should be conveniently located, from which power may be taken, through oil switches, to supply the various feeders. If feasible to do so, the wiring between the transformers, buses, oil switches, and the out-going feeders should be open, as it can be much more economically installed, and is less liable to give trouble than if carried a portion of the way through conduit.

The method of leaving the building with the low voltage feeders will be largely dependent on the type of service, while lightning protection must be provided to suit each individual case. If the voltage is fairly high, say 2,300 to 6,600, with the lines overhead and long distances to feed, arresters should be used; while if the lines are in conduit, static dischargers should be installed. In either case, the protective devices should be mounted with good air spaces all around them, and should have knife switches for disconnecting them from the line. With lower voltages and short feed, the mounting of arresters is a simple matter, and they can generally be well placed with switchboard apparatus.

A few general principles may be added, which, if consistently followed, will largely aid in producing good results.

1st. So arrange your station as to get free operating space and maximum safety to operators, and progress always in one general direction from the point where power enters the station to where it leaves.

2d. Every piece of apparatus should be easily accessible, and so placed that it can be removed without serious interference from the other machinery and fixtures. The wiring should be done so that when one piece of apparatus is removed only those wires which are actually connected to it need be disturbed.

3d. Piping for oil and water to transformers should be placed where it will be clear of apparatus, and so arranged that any transformer may be cut off and removed without interfering with the operation of the others.

4th. Lastly, make all line entrances so that they are good mechanically, and safe electrically.

THE TANTALUM LAMP

BY F. W. WILLCOX

The tantalum lamp was the first metal filament lamp to dispute the supremacy of the ordinary carbon lamp. With the excellent efficiency of 2 watts per candle, it is a material improvement over the ordinary carbon lamp, which requires 3.5 watts per candle for the same length of life as the tantalum, when the latter is operated on direct current. This gives a saving of power with the tantalum lamp of over 40 per cent. for the same illumination, or as the tantalum is not made in sizes less than 20 candle power, a saving of about 35 per cent. over the ordinary 16 candle power lamp of same life (800 to 1000 hours). This material gain in economy has given the lamp a good start in commercial lighting, and over 600,000 of them have been sold in this country. The lamp would have had a wider use but for certain limiting conditions.

In the first place, the tantalum lamp reached its development a little late, coming as it did at the time of the introduction of the GEM, or metallized filament lamp, which gave an efficiency of about 2.5 watts per candle at a cost of but 25 per cent. more than the ordinary carbon lamp, while the tantalum costs three times as much.

Secondly, the reduced life of the tantalum lamp on alternating current (about half that on direct current at ordinary frequencies, 60 cycles or less) practically limits it to direct current service, and this seriously restricts its field of application on central station lines where alternating current is used for the most part. Out of 4000 central stations in this country less than 300 have direct current service, and in number of lamps used, about 40 to 50 per cent. only are on direct current circuits.

Further, the relatively high cost of the tantalum lamp makes it impossible for central stations to supply free renewals as is customary with carbon lamps. This naturally restricts its use among central station consumers, many of whom hesitate to adopt a lamp for which they have to pay when they can get free lamps, even though a clear saving of 20 to 30 per cent. in current, and an increase of 25 per cent. in illumination can be secured. This has necessitated a great deal of advertising and soliciting work to introduce the tantalum lamp.

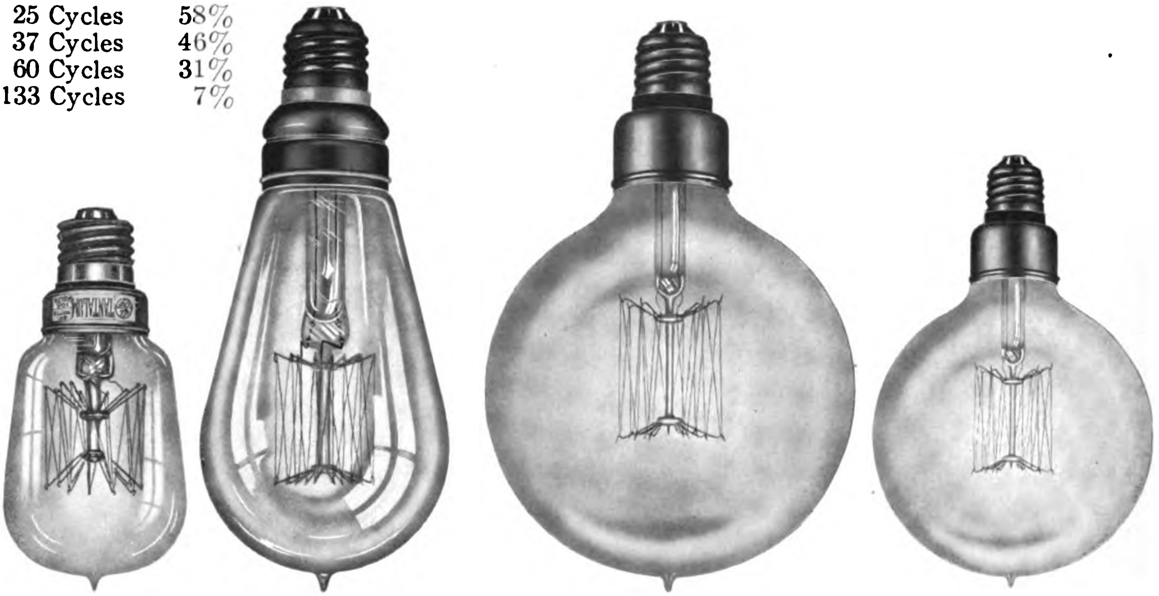
In spite of these limiting conditions, the tantalum lamp has been quite extensively employed in this country since its introduction a year and a half ago. Most of the lamps have been of the 50 watt (25 candle power) and 40 watt (20 candle power) sizes. An 80 watt size is also made, which is used as an incandescent unit with the No. 2 size holophanes. The 40 watt and 80 watt lamps are supplied in the Meridian bulbs, also. The complete line is illustrated in Fig. 1.

The lamp has been received best in central station service where the central station does not supply free renewals of carbon lamps, as customers of such stations, accustomed to buying their lamps, will more readily purchase and try the tantalum. There are, however, relatively few of the direct current central stations that charge for renewals of carbon lamps.

The early difficulties in the manufacture of tantalum lamps have now been entirely overcome, and the present lamps are giving excellent life and very satisfactory service.

The average life on direct current service runs well beyond the guaranteed figure of 800 hours, with many lamps lasting for 1200 hours and more. The life on alternating current service, as is well known, is below that on the direct current. The alternating current life varies with the frequency in about the following ratio:

Frequency	Per Cent. of D.C. Life
25 Cycles	58%
37 Cycles	46%
60 Cycles	31%
133 Cycles	7%



40-Watt Regular **80-Watt Regular** **80-Watt Meridian** **40-Watt Meridian**

Fig. 1. Tantalum Lamps. 2/5 Actual Size

The 40-watt tantalum lamp is naturally the most popular one, since it saves 10 watts (1 kw. hour for every 100 hours of service) over the ordinary 50-watt carbon lamp, and thus pays for its added cost in four to five hundred hours of service at ordinary rates.

Considering its economy, brilliant quality of light, and present excellent life performance on direct current, the lamp should have a wider use. What effect the introduction of the tungsten lamp will have on the tantalum, only time can tell. Present appearances would indicate that it will help to extend the use of the tantalum lamp in the smaller sizes. The tantalum lamp will form a good adjunct to the tungsten, as it is more substantial, cheaper, and more adaptable to the ordinary socket installations. It will therefore probably share in the increased demand for high efficiency lamps created by the tungsten, and be used as a supplement to the latter in locations where it would not be desirable or practical to employ the tungsten.

A large part of tantalum lamp installations has been made on isolated plants. Its most successful service has been given on such plants in relieving overloaded apparatus, and in giving additional illumination without any increase of plant.

The tantalum lamp is of particular value in train lighting service by reason of its high efficiency, and also because it is substantial enough to stand the vibration and rough service. It can be supplied in 10 candle power size, for 30 and 60 volts, in $2\frac{5}{16}$ in. round bulb, and makes a very attractive lamp.

A successful example of the tantalum lamp in central station work is to be found at Muncie, Indiana, a city of 30,000 inhabitants. Provided with an abundant supply of natural gas, distributed by five or more separate companies, and with a widespread use of individual gasoline plants, the electric company has found the use of tantalum lamps a great aid in increasing and holding its customers. Over 10,000 50-watt, 25 candle tantalum lamps have been put into service out of a total amounting to the equivalent of 32,000 16 candle power lamps. Every one of these lamps was sold at 60 cents each, as compared to carbon lamps at 15 cents.

About one half of the tantalum lamps installed are used on a flat rate basis under a two year contract. This rate of 60 cents per month for each 50 watts connected yields an annual income of $144.00 per kilowatt connected. The use of the tantalum lamp, in conjunction with an agressive campaign for business, has assisted to increase the connected incandescent lighting demand 23 per cent. for the past year, in face of most severe competition.

In the lighting of office buildings in the larger cities, such as New York and Boston, the tantalum lamp has proven of marked value. Many such buildings have overloaded lighting plants, or need increased lighting capacity, but do not wish to make additions to their plants, as, aside from the expense involved, it is not possible or practicable in many cases to obtain the additional space required.

Furthermore, the modern office building and hotel must to-day provide a liberal and high grade illumination, and the tantalum lamp gives the distinctively brilliant and attractive quality of light required.

The following large buildings have installed full equipments of tantalum lamps and are realizing benefits in reduction of load and greatly improved illumination.

The Park Row Building, New York City, has 5000 40-watt, 20 candle tantalum lamps in use. In place of the former insufficient and indifferent lighting, the building tenants now enjoy ample illumination of brilliant quality, while the peak of the load has been reduced from 2000 amperes with carbon lamps to 1200 amperes with tantalums. The average saving on the entire load with tantalum lamps is 13 per cent., with a gain of 20 per cent. in illumination.

The Broadway and Maiden Lane Building, New York City, has 6000 40-watt, 20 candle tantalum lamps in service. By reason of other tall buildings which have recently been built around this structure, much natural light has been cut off. This has resulted in an increased demand for electric light, and the use of the tantalum lamp has saved the plant from an otherwise considerable overload.

The Land Title & Trust Co. Building, of Philadelphia, will install over 10,000 40-watt tatalum lamps, saving thereby the expense and trouble of an additional generator.

A most interesting case is the installation of 10,000 40-watt tantalums in the superb new building of the Metropolitan Life Insurance Co., Madison Square and 23d St., New York City. This building is of notable interest by reason of its magnificent and imposing tower, which rises well above that of any other building structure in the world, out-capping even the Singer tower in its sky line. The picture of this building and its massive tower gives an idea of the magnificence of the work as an architectural and engineering feat, and of the striking and artistic effect of the structure as a feature of Greater New York. The building itself occupies an entire block, with a total floor area of 25 acres. The tower just now being completed is the final crowning of the edifice, giving the highest and most massive structure of the kind in the world. Its location opposite the open square of Madison Square Park is a most fitting and fortunate one, as it enables the tower and building to be viewed in full prospective without the obstructing and dwarfing effects of closely adjacent buildings, as in the case of the Singer building tower. Says the *Owners and Builders Magazine:*

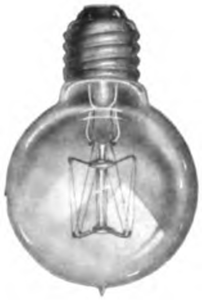


Fig. 2. Tantalum Lamp for Train Lighting. 10 c.p.

"The plans for the building of this tower suggests the famous Campanile, which, for centuries, dominated the sky line of Venice; but two Campaniles might be placed one on top of the other, and they would not be as high as the Metropolitan Life tower. This same comparison may be made with the Madison Square Garden tower. The Metropolitan Life tower will overtop the Singer building in all of its measurements. The Singer tower is 674 feet in height, measuring from the basement to the top of the flagstaff; the Metropolitan tower will be 680 feet from the cellar floor to the top. Measuring from the sidewalk, the new skyscraper on Madison Avenue will be 658 feet, while the Singer tower is but 612 feet to the roof of the topmost lantern, not including the flagstaff. The Singer tower has 47 stories; the Metropolitan structure will have 48 above the sidewalk. The highest lookout in the Singer tower accessible to the public will be the lantern balcony. People looking down from it on the city will stand on a platform 589 feet above Broadway. The highest point for observation in the Metropolitan tower will be the window over the lookout, which is 633 feet above the sidewalk. The difference of 44 feet between the Singer and Metropolitan tower is about the height of the average four-story dwelling house.

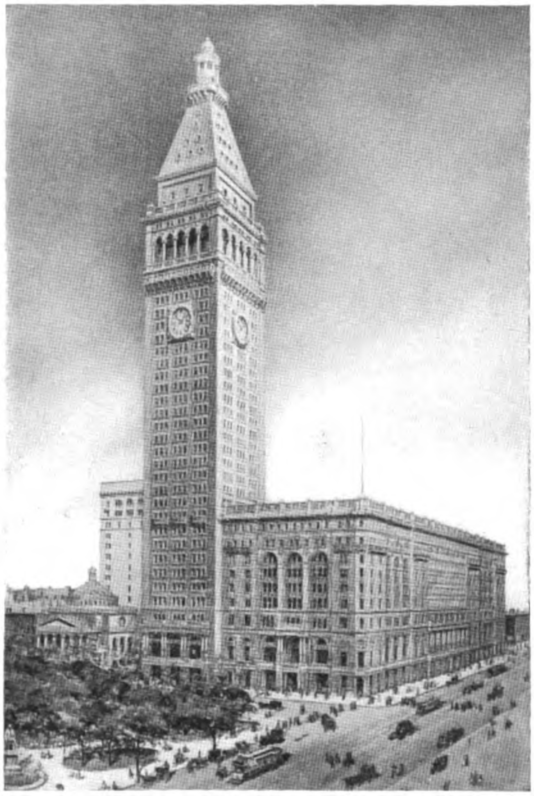


Fig. 3. Metropolitan Life Insurance Building

The Singer tower, which is 65 feet square and 47 stories high, weighs 18,365 tons. The gross weight of the Metropolitan tower will be 84,000,000 pounds, or 37,333 tons. It is, however, 10 feet wider than the Singer tower in one direction and 20 feet wider in the other. The difference in weight is also largely accounted for by the fact that the walls of the Metropolitan structure will be of marble from top to bottom. The Singer tower has corners of brick and terra cotta, and central panels of metal and glass.

Engineers usually regard wind pressure of 35 pounds to the square foot as ample for the big skyscrapers. But the conditions which surround the Metropolitan tower are unusual. Standing on a corner and facing Madison Square, with no neighboring towers to break the force of the wind, it is in a sense isolated, and must be self sustaining. The engineers, therefore, in their calculations, increased the allowance for wind pressure from 35 to 60 pounds for the square foot. This will allow for a higher wind than has ever yet been experienced in New York.

The 1,400 windows which will pierce its walls would be sufficient for sixty dwellings of the average four story type.

The building of the Metropolitan Life tower will require 8,135 tons of steel—enough for seven twelve-story skyscrapers, covering a site of the same size, 75 by 85 feet. The lower pillars are remarkable for their weight and dimensions. The corner columns, 38 inches square, weight a trifle more than a ton for every square foot.

In the building of this tower more than 40,000 barrels of cement will be used. Much of it will go into the floors, which will be different from those of the ordinary skyscraper, the latter usually being of terra cotta blocks, held together with cement. In all, 9,000 cubic yards of concrete and fire-proofing will be required for the tower.

At the twenty-fifth, twenty-sixth and twenty-seventh stories, or 334 feet above the sidewalk, there will be a great clock, which will prove a seven-days' wonder for New York and her visitors from foreign shores. This clock is indeed a marvel, in the way of size at least. Its face will be twenty-five feet in diameter, its hands twelve feet in length, and the figures marking the hours and minutes four feet long. It will be possible to tell the time by this monster clock miles in the distance, and the height at which it is to be placed will enable it to show above the surrounding houses, so that it will be of service to persons living far away from its location. There will be four dials, one on each side of the tower, so that every point of the compass will be served by the big clock.

For the transportation of visitors to the several floors of the tower, six express elevators will be installed. Five of these will terminate their trips at the forty-first story and the sixth at the forty-fourth story. The twelve lower stories will be served by the elevators in the adjoining section of the main building, the present elevator corridor giving direct access to the tower. All motive power, heat and light will be supplied by the plant now installed in the main building.

The estimated cost of the erection of this marble tower is placed at about $3,000,000. The ground represents an investment of nearly $1,000,000. To this fully $2,000,000 must be added as the cost of the tower itself. The steel in the structure alone will cost $250,000.

The general dimensions of the great tower are shown in the following table:

Frontage on Madison Ave.	75	feet
Frontage on Twenty-fourth St.	85	"
Height above sidewalk	666	"
Height from cellar floor to top	688	"
Total height from foundation to grillage beams	698½	"
Height of clock face above sidewalk	346	"
Height of loggia floor above sidewalk	392½	"
Top of loggia balustrade and offset level above sidewalk	453	"
Floor of lookout (45th story) above sidewalk	603	"
Center of window over lookout (highest point for observation) above sidewalk	633	"
Tonnage of iron in tower, equal to the entire tonnage of metal in balance of building	8,200	
Number of stories above sidewalk in tower	48	
Number of stories below sidewalk in tower	2	
Total number of stories in tower	50	
Number of cubical feet in tower	3,515,493	
Total net rental floor area, tower (exclusive of walls and corridors)	153,359	
Number of cubical feet in Metropolitan building (exclusive of tower and courts)	12,771,541	
Grand total of cubical feet in Metropolitan building	16,287,034	
Grand total floor area Metropolitan building (about 15 acres)	1,085,663	

SOME FACTORS AFFECTING STATION CONNECTIONS AND SWITCHING ARRANGEMENTS

By R. E. Argersinger

Power and Mining Department, General Electric Co.

In laying out an electrical plant, after determining the number and size of generating units, the general character of the service, and the number of out-going feeders, the next point to be considered is the general system of connections.

Generating stations may be divided into two classes, the first class comprising those stations in which power is generated and distributed at the same voltage. These stations are rarely operated at voltages higher than 13,200, and may be sub-divided into two groups:

(a) Where a small amount of power is to be transmitted to a moderate distance; and,

(b) Where a large amount of power is to be distributed in the immediate vicinity of the station.

The first group is of no particular interest, as far as station connections go, since stations in this group will usually include only one or two machines, with one or possibly two transmission lines. Group (b), however, covers a large number of plants used for lighting and railway purposes, which usually contain a number of generators and a larger number of outgoing feeders. It is also important in this class of service that the power supply be continuous under all sorts of conditions, and, consequently, elaborate switching arrangements are installed.

Since it is the purpose of this article to discuss briefly only stations for general power service, we wish to point out only one or two interesting features in connection with the general class under (b).

In small plants, one main operating bus, on which all the machines are paralleled, and from which all the feeders are tapped off, is generally sufficient; but when the number of machines becomes large, and especially when a considerable number of feeders are required, it is necessary to install two buses, and in some cases even three or four. The Edison systems are good examples of this procedure. By means of these multiple buses it is possible to subdivide the service; operate different feeders at different voltages; confine all operations to one bus in case of trouble on the other; or to inspect or clean the bus or switches connected to it. In order to obtain the maximum flexibility from a multiple bus arrangement, it is necessary to connect each unit, or each feeder to each bus, through an oil switch so that all switching can be done under load. In some cases, however, where the cost of this large number of oil switches is prohibitive, disconnecting knife switches may be used, which will serve to connect the generator or feeder to the bus after the current is cut off by means of a single oil switch. A second important point in connection with the feeder arrangement is the use of group switches; *i. e.*, switches which are used as ties between the bus and a group of feeders, numbering perhaps four or six, or even more. Such a switch serves to conveniently operate a number of feeders which may supply an interconnected service, or to separate feeders subject to similar operating conditions; and also, in case of trouble in the station, it affords a means of more rapidly disconnecting the load than if each feeder switch had to be tripped individually. In many cases, in stations of this character, a benchboard is of considerable advantage over the vertical panel board. A benchboard allows the control to be confined within a small space by means of electrically operated switches, and consequently increases the convenience of operation. It may happen, however, that the number of instruments is very large compared with the number of switches, and consequently, that the panel board supporting the meters is much more extensive than the benchboard taking care of the control, with the result that when the operator stands at the bench he is too far from the meters on the circuits controlled to read them conveniently. In such a case a bench is of no advantage over the panel board.

The second class of generating stations includes those in which the voltage is stepped up by means of transformers, and the station output distributed over a comparatively small number of lines. This class of stations covers practically all of the large power developments. The simplest arrangement of connections for such a plant can be used when the number of generators, transformers and outgoing lines are the same. This system is commonly called a unit system. Under such conditions each unit, consisting of its line, transformer and generator, will ordinarily be operated independently, and a bus arrangement, sufficient only for transferring from one line to another, or from one transformer to another in case of emergency, is all that is necessary. The most common modification of this system is found in the station where the number of transmission lines is less than the number of transformer banks. This arrangement necessitates the use of a high tension bus on which the transformers may be paralleled, and from which the outgoings line may be taken. If the number of transformer banks does not greatly exceed the number of lines, a single bus should be sufficient, although it will usually be found convenient to sectionalize this bus at such points as will serve to isolate certain portions of it for repairs or cleaning; or in order to isolate a line (which may have broken down electrically), with certain transformers and generators, in order to test it before again placing it in service.

If the number of lines is small compared with the number of transformers, a single high tension paralleling bus is insufficient, since the bus then becomes a very important operating feature, and it is hardly safe to trust to a single bus for the continuous operation of the station. The most flexible arrangement is the duplicate bus, each bus being connected to the lines and to the transformer banks through oil switches. The lines or transformers can then be connected to either bus without interrupting the flow of current. The expense of this arrangement may be reduced by placing an oil switch in the line and one in the transformer circuit, and connecting them to either bus through an air break switch. This still allows any line or transformer to be connected to either bus, but the switching must be done at no load. A still cheaper arrangement consists of a "ring bus;" *i. e.*, a single paralleling bus sectionalized between each group made up of a line and the transformers directly feeding it, the two outer ends of the bus being connected together through an oil switch. This involves practically a second bus running across the station, but eliminates the cost of the additional set of switches required by the ordinary duplicate bus. In some cases it may be feasible to make this ring connection outside the station. This bus arrangement allows any section to be cut out without interfering with parallel operation, and, by proper low tension bus connections, the generators feeding the section cut out may usually be transferred to other transformer banks, the overload capacities of which should be sufficient to carry the entire station output until the high tension bus section can be again put into service. The ring bus, to be of any advantage, must be operated with at least three (preferably more) transmission lines in parallel.

The arrangement of low tension buses will depend to a great extent on whether or not there is any low tension distribution. If considerable power is to be distributed in the vicinity of the station at the generated voltage, it will often be found advisable to use a double set of low tension buses so as to separate the local power from that to be distributed at the high tension voltage. The generators on the buses should be separated accordingly, since the requirements of voltage control on low tension feeders often necessitate special regulation for the low tension distributing bus, which regulation does not apply to the power transmitted at the high voltage.

The double bus also allows the isolation of any generator and the low voltage side of any transformer bank for purposes of testing, as mentioned above, or the operation of any transformer bank with any generator. In order to accomplish the two latter results with only one bus, a transfer bus is often used. This consists of one bus connected through a switch to the line between the generator and transformers. By keeping at least one generator always connected to such a bus, it will also serve as a source of low voltage power for station purposes. Where the number of generators and transformer banks is the same, the transfer bus allows more flexible operation than a single bus to which all generators and transformers are tied directly in parallel. If the units are of large capacity it will usually be of advantage to make the connection to the transfer bus through an oil switch, so that any switching which is necessary may be done under load; and further, by using an electrically operated switch it may be operated from the main control board. In the case of smaller stations, however, and where the service is such that the switch will have to be used only infrequently, a knife switch will usually be satisfactory. This is advisable, especially where transferring is to be done for testing purposes only, or for similar purposes.

Where the number of lines, transformers and generators are all different, it is necessary to have both high and low tension buses, and to operate the generators in parallel on the low tension bus and the transformers in parallel on the high tension bus. If any transferring is to be done on the low tension side, a double bus is necessary. If it is expected to use the double bus only in cases of testing or emergency, it will usually be sufficient to install one oil switch in the generating circuit, with knife switches leading from it to each bus, a similar arrangement being used on the low tension side of the transformer bank. If, however, the double bus is expected to be used frequently, or if the units are large, or if there is considerable local service, it will be advisable to use oil switches for connecting the generator and transformer circuits to each bus, a disconnecting switch being used to isolate the generator and transformer from the bus tie line.

Any double bus arrangement, for either high or low tension, is expensive, not only as regards the bus itself and the space taken by it, with the consequent increase in the size of the station, but also because of the large increase in the number of switches which it necessitates. Therefore, the actual need of a double bus should be carefully considered before it is installed.

In considering the switching arrangements for any given station, the character of the automatic control is an important feature. While outgoing feeder switches are nearly always automatic on overload, it is usually of advantage to have a time element in connection with such automatic operation so that the line switches will not be tripped in case of a slight ground or similar momentary trouble. Consequently, the automatic switches on outgoing lines are usually equipped with time limit relays. The switches controlling the high and low tension sides of transformer banks should also be automatic in order to cut out a bank of transformers in case of internal troubles. Where transformers are paralleled on the high and low tension sides, if three or more banks are installed they may be isolated by the use of inverse time limit relays, since in case of trouble in one bank the current will be fed into the disabled transformer from the two banks still in operation. As the current flowing through the relays on the bank in trouble will be twice that in the relays on the other banks (assuming three transformer groups), the inverse feature of the relays will operate the switches on the bank in trouble before the switches on the remaining two banks open, so that the disabled bank will be cut out without shutting down the station. If only two transformer banks are in parallel, the inverse relay will not be effective, since the current operating both relays will be the same. In such a case a differential reverse current relay must be employed, connected to current transformers on either side of the main transformer bank. This relay will not operate as long as the power is fed through the bank of transformers in its normal direction, but in case of trouble the current flow from one side of the transformer bank will be reversed, with a consequent operation of the relay and opening of the switches on both sides. As a rule, generator switches are non-automatic, in order to avoid their automatic opening in case of heavy overload, or line or transformer trouble. Such an opening would mean the necessity of synchronizing all the generators after any severe overload—a condition of affairs which would be very inconvenient. The only objection to this arrangement is, that in case of short circuit in the generator wiring, or in the low tension bus, there is no means of automatically cutting off the machines; but such trouble is so rare that the disadvantages of automatic switches more than outweigh the objections against the risk due to making these switches non-automatic.

It should be borne in mind in laying out any system of station connections where high voltages are used, that metering should be confined to the low tension circuit just as much as possible. Instrument transformers for high voltages occupy considerable space, and are very expensive. Series relays have been developed so that automatic switch operation can be obtained without installing high voltage current transformers, and series ammeters are also being used to some extent as current indicators, placed directly in the high voltage outgoing lines. Under such circumstances, the necessity for high voltage current and potential transformers should be very carefully weighed before an arrangement is made calling for their use.

The above remarks apply, in a general way, to sub-stations as well as to main stations, especially in the case of large distributing sub-stations taking power from a long transmission line. In connection with smaller stations, however, there are one or two points to which attention might be called. Where only one station is fed from one transmission line, specifications are sometimes drawn up calling for oil switches to control the incoming line. Usually there is an oil switch at the generating station end of the same line, with the result that two switches are unnecessarily in series. The sub-station line switch should, in such a case, be of the open air break type, allowing all automatic switching to be done on the main station switch.

When small sub-stations are tapped off from transmission lines, the character of the incoming line switch should be given careful consideration. If, as is usually the case, there are a number of these small sub-stations feeding from the same line, it is not desirable to allow any trouble on one of the sub-station feeders to open the transmission line switch in the main station. To avoid this, the automatic switch on the sub-station incoming line must be of sufficient capacity to rupture the entire kilowatt capacity back of the transmission line. This may mean an oil-switch with a rupturing capacity of say 20,000 kw., in a sub-station of only 400 or 500 kw. output. In such a case the use of high tension expulsion fuses is to be recommended. These fuses are considerably cheaper than the oil switch of corresponding rupturing capacity, and as they are only expected to operate automatically under emergency conditions, they are very satisfactory. By properly protecting them they may be installed on the outside of the station, with a consequent saving in the sub-station area.

In general, any system of connections should be decided upon only after a careful consideration of the service which the station is expected to supply, and of the arrangement of the generating units. As in all other engineering problems, the relative advantages of flexibility obtained from any arrangement must be balanced against the expenses involved in obtaining such advantages.

TURBINES AS DRIVERS FOR CENTRIFUGAL COMPRESSORS AND PUMPS

By B. F. Bilsland

Power and Mining Department, General Electric Co.

Centrifugal compressors and pumps are so called because the pressure which they impart to a gas or liquid is due to centrifugal force. On account of the relation existing between centrifugal force, speed, and the radius of the path of rotation, such compressors and pumps can be most economically built with small diameters, for operation at high angular velocities. Therefore, direct connected prime movers, when used for driving such machines, must be of extremely high speed. The steam turbine is especially applicable to such work on account of the high speed at which it normally operates, and because of its compactness, and uniformity of rotation.

The General Electric Co. has recently developed a line of high speed steam driven compressor sets, and has also furnished several turbines for direct connection to centrifugal pumps, some of which will be described in the course of this article.

The turbines may be condensing or non-condensing, for high or low pressure, just as in the case of prime movers for electric generators; although the most simple and inexpensive, and consequently the most widely used machine for this work is the high pressure, non-condensing turbine.

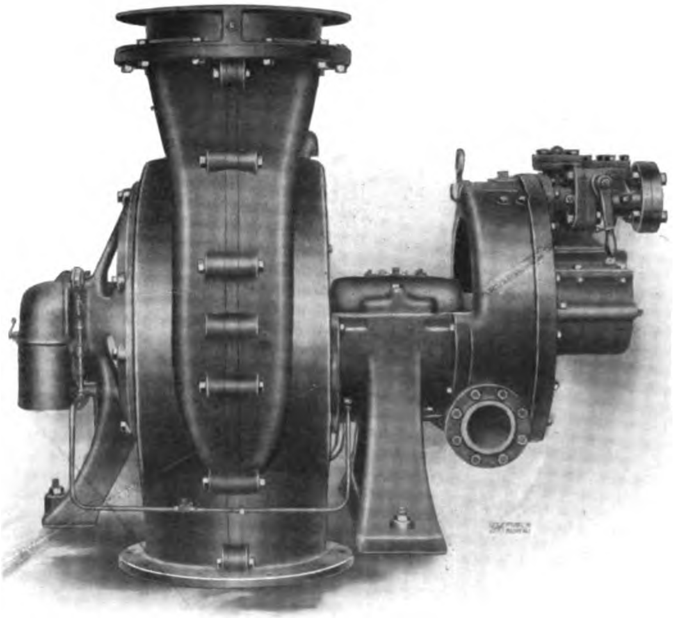


Fig. 1. Curtis Turbine Driven Air Compressor

There is, however, a large field for the application of low pressure turbines to the driving of compressors and pumps, as there are many plants operating with reciprocating engines where a compressor or pump driven by a low pressure turbine could be installed and operated with practically no expense except the initial cost.

The turbines are of the horizontal Curtis type, which was described in the May Review by Mr. R. H. Rice; it is therefore unnecessary to give a description of their construction or operation in this article.

The compressors are even simpler than the turbines, each unit consisting of only casing, impeller, bearings, and guide vanes. The air in entering is conducted to the center of the impeller, scooped up by the impeller blades, and thrown into either the guide vanes or outward channel of the compressor casing. Higher pressures than can be produced economically by one such unit or stage are obtained by operating several units in series, as is done in the multi-stage centrifugal pump.

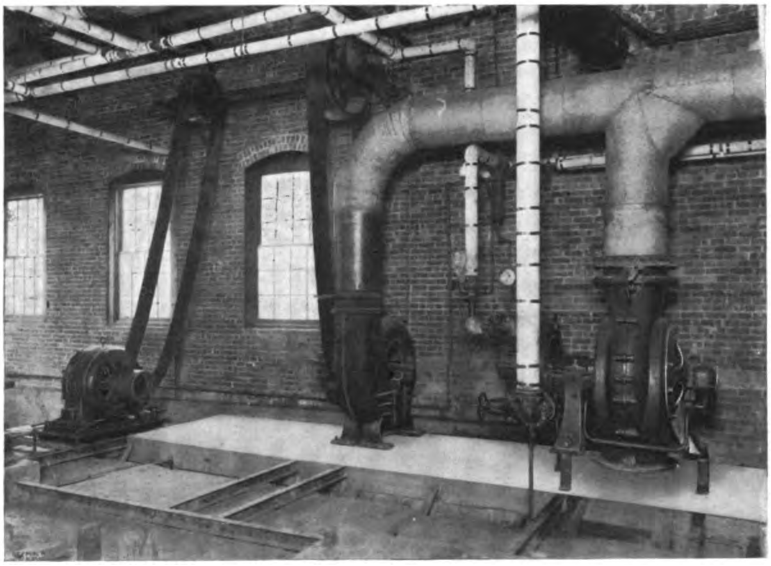


Fig. 2. Turbine Driven Centrifugal Compressor and Motor Driven Blower in Gas Plant

Owing to the wide range of the turbine speed, any reasonable variation in pressure can be obtained by an adjustment of the turbine governor. This is of great value in some installations. As the turbines that are used for driving these compressors were originally designed for driving electric generators, they are arranged with a closely regulating governor, with the result that a very steady pressure is maintained by the compressor.

While the turbines are capable of giving close regulation and steady pressure, they are of equal value for driving compressors operating on an intermittent service, as the rotating element may be brought up to speed as fast as the friction can be overcome and the necessary energy transmitted to the element. In the case where first cost is an important factor, regulation and economy may be sacrificed by arranging the turbine with a simple throttle governor.

The compressors which have been laid out and considered as standard, range in capacity from 750 to 10,000 cu. ft. of free air per min., with a normal pressure of 0.88 lbs. to 2.7 lbs. per sq. in., and a maximum pressure of 1.5 lbs. to 4.2 lbs. per sq. in. Compressors are being developed, however, which will deliver a pressure of 30 lbs. per sq. in.

A typical turbine driven compressor is shown in Fig. 1. This compressor is rated at 7000 cu. ft. of free air per min., compressed to a pressure of 0.88 lbs. per sq. in. It is driven by a 50 h.p., 3500 r.p.m., non-condensing turbine. The duty of this compressor is to furnish air for making gas.

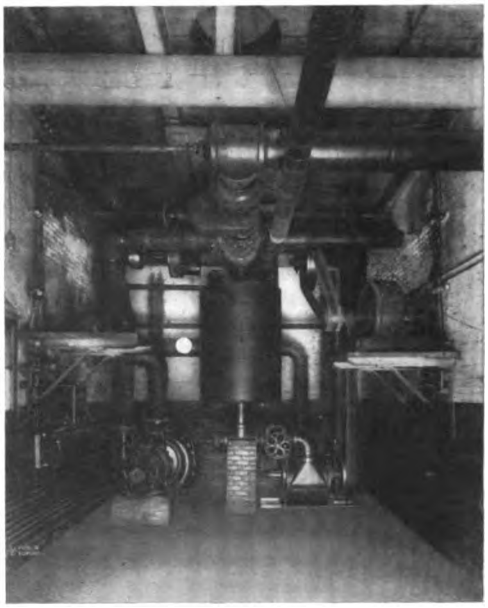


Fig. 3. Centrifugal Compressor and Positive Pressure Blower

Fig. 2 shows the set as installed by the Mohawk Gas Company, at Schenectady, N. Y. The compressor is shown supported at three points by iron brackets resting on I beams, which have lately been grouted in. The set was started and operated for some time, being supported wholly by the I beams with no grouting, and the operation was perfect. The users and operators are perfectly satisfied with the machine, and cannot speak too highly of it.

The compressor is operated without an inlet pipe connection, and some noise is caused by the air rushing into the opening; this will be entirely eliminated, however, when the permanent intake pipe is installed, the mouth of which is to be located outside of the building. The bearings are supplied by forced lubrication, arranged in the same manner as for our small turbo-generating sets, the pump being located at the outer compressor bearing and driven by means of a worm gear on the shaft.

A motor operated blower, driven by means of belts and shafting, is used as a spare unit, and is also shown in Fig. 2. It is needless to compare the efficiency, compactness and neatness of the sets.

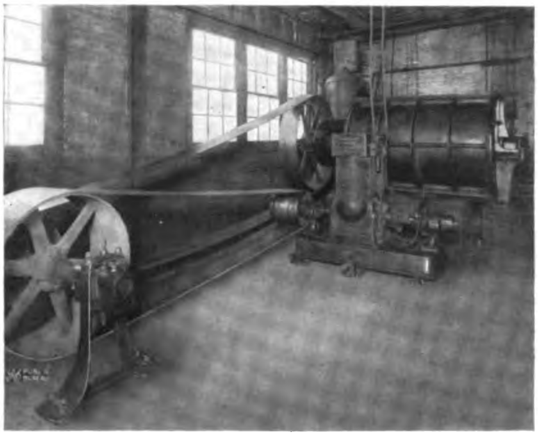


Fig. 4. Motor Driven Positive Pressure Blower

Leaving the turbine driver for a minute, a typical installation and comparison of our centrifugal compressor and positive pressure blower (constant volume) is shown in Fig. 3. These compressors are installed in the oil house at the Schenectady Works of the General Electric Company. The centrifugal compressor is rated normally at 1400 cu. ft. of free air per min., compressed to 1.7 lbs. per sq. in., and is driven by a 20 h.p., 250 volt, direct current motor of the turbo-generator type, the set operating at 3450 r.p.m. This set has been in operation sometime, and has given entire satisfaction. The engineer who has these sets to look after, states that he can get a great deal more out of the centrifugal compressor, and that its pressure gauge, which consists of a column of mercury, is very much steadier than that of the blower. Practically the only attention this machine requires in operation is an occasional adjustment of speed by means of the motor field to compensate for variations in the line voltage.

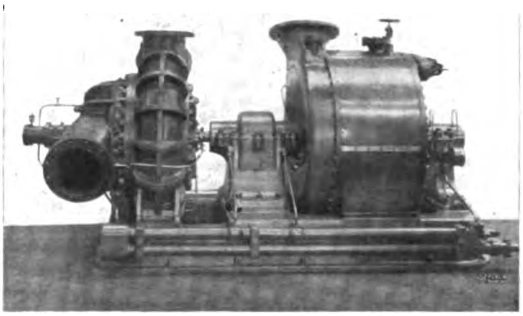


Fig. 5. Turbine Driven Pump for New York City Fire Boat

The positive pressure blower, which is of approximately the same capacity, is driven by a direct current motor by means of pulleys, belts and shafting, as shown. The blower requires a large receiver tank to equalize the pressure and relieve the mains of pulsations and shocks. The receiver tank is entirely unnecessary with the centrifugal compressor, as the latter gives a constant, continuous pressure. Also, the space occupied by the receiver tank alone is greater than that required by the entire direct connected centrifugal compressor set. From the comparison and illustration, you can readily arrive at the relative costs of the two sets.

The installation shown in Fig. 4 is a further illustration of a positive pressure blower. This machine is installed in the iron foundry at the Schenectady Works of the General Electric Company. It is a typical installation, consisting of a mass of belts and pulleys, and occupies a large amount of space. The capacity of this set is approximately the same as that of the turbine driven set shown in Fig. 1.

There is no comparison between these installations in first cost, efficiency, space occupied, satisfaction of operation, and appearance. Another point where the compressor excels the old style blower is in its quietness of operation. While the centrifugal compressors make a slight noise, due to the impellers rotating at such high speeds, this is not of an objectionable nature, and is a negligible quantity when compared to the noise of a positive pressure blower, occasioned principally by the belts, meshing of compressor parts, and driving gear.

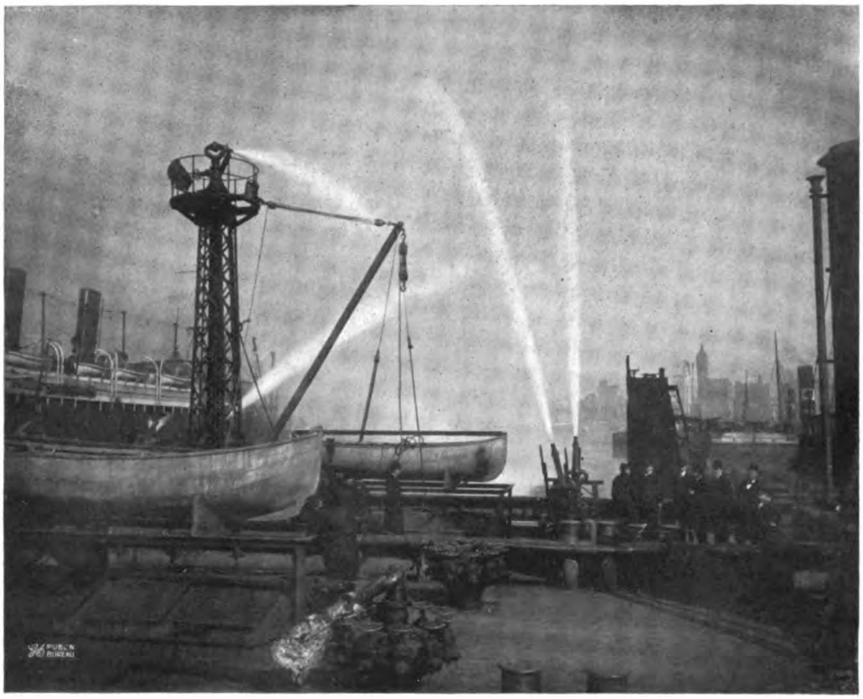


Fig. 6. Trial of Turbine Driven Pump for New York City Fire Boat

In addition to compressors, the steam turbine is well adapted to driving high speed centrifugal pumps, and has been successfully applied to this work in several instances. It is sometimes difficult, however, to obtain a pump which will operate at a speed sufficiently high for the turbine to make its most favorable showing, since pump builders have not fully awakened to the advisability of building small pumps for such speeds. That there is a large field for such sets is shown by the abundance of inquiries for turbine driven pumps.

The General Electric Co. has recently completed an important turbine pump installation on two fire boats for New York City. Fig. 5 shows one of the turbine driven sets, two of which have been installed on each boat. The pumps are rated at 4500 gals. per min., against a head of 150 lbs. per sq. in. The turbine is rated at 600 b.h.p., at 1800 r.p.m., operates condensing, and is of the four-stage type.

An automatic controlling governor is not used with these turbines, but instead they are arranged for hand control by means of five hand operated valves, each valve giving approximately one-fifth the maximum capacity of the turbine. The standard emergency governor and combined emergency throttle valve are employed, the emergency governor being adjusted to operate at 15 per cent. above normal rated speed.

These machines have met the guarantees made for them, and Mr. Croker, Chief of the New York Fire Department, has expressed himself as being very well pleased with them.

The pumps were given a trial test after installation on the boats. They were operated in series, and under these conditions threw two three-inch streams, at three hundred pounds pressure, as shown by Fig. 6 and the illustration on page 298.

These cuts are interesting from the point of general design of the fire boats, as well as from the fact that they show what actually takes place in case of a fire along the docks. A general idea is given, of the appearance of the towers, and in Fig. 6 the water main heads are clearly shown, from which an idea may be had of the number and size of hose which can be attached to them.

Another fire boat equipment is at present being completed for the Chicago fire boats. The general scheme and advantages of this installation were outlined by Mr. J. H. Clark in the August, 1907, Review. One of these sets is shown in Fig. 7.

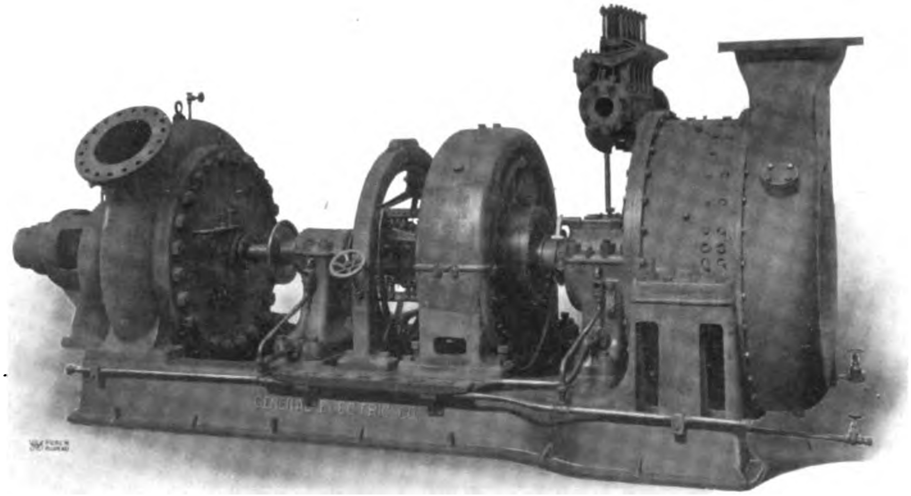


Fig. 7. Turbine Driven Generator and Pump for Chicago Fire Boats

In general, each unit consists of a three-unit, three-bearing set, with a common bed plate. The driver is a two-stage, 660 h.p., 1700 r.p.m., condensing turbine of the overhung type, which is direct connected to a 200 kw. (maximum capacity), 275 volt, direct current generator of the turbo-generating type, and a 4500 gal. per min., 150 lb. pressure centrifugal pump. The turbine rotor and generator are mounted on a one piece shaft carried by two bearings. The pump is connected to the shaft and driven by means of a flexible weight carrying coupling, the pump bearing being located in the outer portion of the pump casing.

Each of the machines composing the set is of practically standard design, but the arrangement of the combination, and the scheme of operation is entirely new. The operation is described in Mr. Clark's article, as mentioned. Briefly it is as follows: The turbine drives both the generator and pump continuously, the former being used to generate power for the motors which drive the screws, and the latter supplying the water for fighting fires. The turbine is equipped with standard poppet valves, arranged for hand control by means of a cam shaft, rack and pinion. An emergency governor of the usual type is supplied. The bearings are supplied with oil under pressure, and are of the water-cooled type. Two of these sets are being tested at the Schenectady Works of the General Electric Co., and are giving satisfaction, both as to operation and efficiency.

LIGHTNING AND LIGHTNING PROTECTION

By Charles P. Steinmetz

With the change in the character, the size, and the power of electric circuits, the problem of their protection against lightning has also changed, and has become far more serious and difficult. Forms of lightning have made their appearance which did not exist in the small electric circuits of early days, and protection is required not only against the damage threatened by atmospheric lightning, but also against lightning originating in the circuits, and called "internal lightning," which is frequently far more dangerous than the disturbances caused by thunder storms.

The principal difference between lightning, in its broadest sense, and the normal flow of power in an electric circuit is, that lightning is the phenomenon of electric power when beyond control. It is therefore the same difference that exists between a useful fire and a conflagration; and just as we would hardly call a small bonfire a conflagration, so also we do not call electric power which is beyond control, lightning unless it is of destructive value.

Electric power, when getting beyond control, may mean excessive currents or excessive voltages. Excessive currents are rarely of serious moment, since the damage done by them is mainly due to heating, and even very excessive currents require an appreciable time before producing dangerous temperatures. Usually, circuit breakers, automatic cut-outs etc., can take care of heavy currents, the only damage done by such currents being when they occur at the moment of opening or closing a switch by burning the contacts, or where the mechanical forces exerted by them are dangerously large, as with the short circuit currents of the huge modern turbo-generators.

Excessive voltages, however, are practically instantaneous in their action, and the problem of lightning protection is essentially that of protecting against these excessive voltages, or electric pressures.

The performance of the lightning arrester on an electric circuit is therefore analogous to that of the safety valve on the steam boiler; that is, the function of both is to protect against dangerous pressures—steam pressure or electric pressure—by opening a discharge path as soon as the pressure approaches the danger limit. Absolute reliability in the operation of the device is therefore required, with a discharge producing as little shock as possible, and over a path amply large to carry off practically unlimited power without dangerous pressure rise.

Dangerously high pressures may enter the electric circuit from the outside, due to atmospheric disturbances such as lightning, or they may originate in the circuit.

Excessive pressures in electric circuits may be single peaks of pressure, or strokes, discharges, or multiple strokes, meaning by the latter several strokes following each other in rapid succession, with intervals between strokes varying from a small fraction of a second to a few seconds; or such excessive pressures may be practically continuous, that is, with strokes following each other in rapid succession, thousands per second, continuing sometimes for hours.

Atmospheric disturbances, such as cloud lightning, usually give single strokes, but quite frequently multiple strokes. As shown by the oscillograms of lightning discharges from transmission lines which were secured by Prof. Creighton last year, multiple lightning strokes are very common; therefore, to properly protect the system, a lightning arrester must be operative again immediately after the discharge, since very often a second and a third discharge follow within a second of time, or less. Consequently, a lightning arrester which depends on the operation of mechanical parts to reset itself after a discharge, fails to protect against a multiple stroke.

Continuous discharges, or recurrent surges; *i. e.*, lightning lasting continuously for long periods of time, with thousands of high voltage peaks per second, mainly originate in the circuits due to an arcing ground, spark discharges over broken insulators, faults in cables, etc., and are a phenomenon which has made its appearance only with the development of the modern high power high voltage electric systems, becoming of increasing severity and danger with the increase of size and power of electric systems.

Single strokes and multiple strokes, or in other words, all disturbances due to atmospheric electricity, such as cloud lightning, are safely taken care of by the modern multi-gap lightning arrester. As this arrester has been described repeatedly, it needs no description here beyond the statement that it comprises a large number of spark gaps connected between line and ground, and shunted by resistances of different sizes in such manner that a high pressure discharge of very low quantity, such as the gradual accumulation of a static charge on the system, discharges over a path of very high resistance, and. is inappreciable, and frequently invisible. A disturbance of somewhat higher power finds a discharge path of moderate resistance, and so discharges with moderate current, without shock on the system; while a high power disturbance finds a discharge path over a low resistance, and, if of very great power, over a path of zero resistance. That is, the resistance of the discharge path with the present multi-gap lightning arrester is approximately inversely proportional to the volume of the discharge. This is an essential and important feature. Occasionally, discharges occur of such large volume as to require a discharge path of zero resistance, as any resistance at all would not allow a sufficient discharge to keep the voltage within safe limits. At the same time, the discharge should not occur over a path without resistance, or of very low resistance, except when necessary, since the momentary short circuit (short circuit for a part of the half wave) of a resistanceless discharge is a severe shock on the system, which must be avoided whenever possible.

This type of lightning arrester takes care of single discharges and of multiple discharges, with the minimum possible shock on the system, no matter how frequently they occur or how rapidly they follow each other. It cannot, however, take care of continuous lightning; *i. e.*, those disturbances, mainly originating in the system, where the voltage remains excessive continuously (or rather rises thousands of times per second to excessive values), and for long periods of time. With such a recurring surge, the multi-gap arrester would discharge continuously in protecting the system, until it was destroyed by the excessive power of the continuously succeeding discharges.

Where such continuous lightning may occur frequently, as in large high power systems, and where the system requires protection against them, a type of lightning arrester is necessary which can discharge continuously without self-destruction, at least for a considerable time. The only lightning arrester which is capable of doing this is the electrolytic, or aluminum arrester. In its usual form (cone type) it comprises a series of cone shaped aluminum cells, connected between line and ground through a spark gap. As soon as the voltage of the system rises above normal to the value for which the spark gap is set, discharges take place through the aluminum cells over a path of practically no resistance. However, the volume of the discharge which passes is not produced by the normal voltage on the system, but is merely due to the voltage over the normal, since the normal voltage is held back by the counter e.m.f. of the aluminum cells. As a result, with thousands of strokes per second following each other, or in other words, with a recurrent surge, the aluminum arrester discharges continuously. As it can stand the continuous discharge for half an hour or more without damage, it protects the circuit against continuous lightning for a sufficiently long time for the cause of the high voltage to be found and eliminated.

Even the cone type of aluminum arrester discharges with a slight shock on the system, since the voltage must rise to the value of the spark gap before the discharge begins; therefore, in systems where even a small voltage shock is objectionable, as in large underground cable systems, and also in cases where it is necessary to take care of recurrent surges for an indefinite time, the no-gap aluminum arrester becomes necessary. In principle, this type is the same as the cone type, but the aluminum cells are connected between the conductors and the ground without any spark gap, and are continuously in circuit, taking a small current. For this reason the cells are made larger and of different construction, so as to radiate the heat from the current, which, while small, would still give a harmful temperature rise if allowed to accumulate. Being continuously in circuit, a no-gap aluminum arrester allows no sudden voltage rise whatever. Its action is similar to that of a fly wheel on an engine—while it allows gradual changes of voltage, any sudden change of voltage is anticipated and cut off, just as any sudden change of speed in an engine is checked by the fly wheel. The no-gap aluminum cell, therefore, can hardly be called a lightning arrester, but rather fulfills the duty of a shock absorber, or of an electrical fly wheel, on the voltage of the system, and as such finds its proper place on the busbars of the station or substation.

CARE AND INSPECTION OF LIGHTNING ARRESTERS

By V. E. Goodwin

Power and Mining Department, General Electric Company

The fact that no piece of apparatus in an electrical transmission system has a more difficult function to perform than the lightning arrester equipment, is very often overlooked by operating and designing engineers. Lightning arresters are frequently placed in the most inaccessible places, and as a rule are never inspected or adjusted after their installation. These arresters operate satisfactorily for a few months or a year, and then perhaps suddenly fail to extinguish the dynamic arc, and shut down the system. These failures at present represent only a small per cent. of the total number of arresters which the General Electric Co. has installed, but I believe they could be reduced to an inappreciable number if proper care and inspection were given the arresters, provided, of course, that proper arresters have been installed to meet the requirements of continuous lightning.

A few operating companies have realized the importance of proper inspection of arresters, and have a specialist on protective apparatus whose duty it is to examine the lightning arrester equipments systematically, and to report the results of each storm or lightning disturbance on their system.

To be complete, this report should contain at least the following items regarding each storm:

1. Date of each disturbance.
2. Cause and location of the trouble.
3. Interruptions to service, time and location.
4. Damage to apparatus, giving location and name of apparatus damaged.
5. Action of the arrester. (See note below)
6. Estimated protection afforded.
7. Condition of telephone service.
8. General comments.

In making reports special attention should be given to the nature of the lightning, as described elsewhere in this issue by Dr. Steinmetz. In every case it is important to determine if any accidental grounds occurred on the system, and when possible, if the principal disturbance was a primary or secondary effect of lightning.

Once each year a general report should be made out containing a summary of the reports on individual storms. This annual report should be carefully compared with those of previous years, noting especially any increase in the size of the system, and the character of the new apparatus; also, a comparison of the interruptions and damages to apparatus, and of changes, if any, in the lightning protective devices.

The action of the arrester should be intelligently and carefully studied. This can best be done by means of tell-tale papers placed in various sections of the arrester. For this purpose a specially treated fireproof paper should be used. These papers allow punctures of various sizes, depending upon the amount of discharge, but will not take fire and burn up as is often the case with the ordinary test papers.

It is of the utmost importance that arresters of any type be examined systematically every day, and also after every electrical storm or discharge. The punctured test papers should be collected at the same time and carefully filed. It should also be seen that there are no loose connections, and that the gaps are in proper condition. Since the knurled points along the gaps burn away with a number of discharges, the cylinders should be occasionally turned on their spindles so as to present new surfaces for discharge. Arresters should be kept free from dust, which may accumulate in the gaps or on any of the working parts. If a compressed air jet is not available, a pair of hand bellows will be found convenient for this purpose.

All repairs on arresters should be made promptly, and no arrester should ever be reconnected to the line in a damaged condition. Direct current railway arresters are probably given less attention than even the high voltage types. The type of apparatus used for this service has a very much lower puncture value than that used for high voltage service, and it is therefore imperative that these protective devices be more properly adjusted and inspected.

One of the great advantages of the aluminum cell arrester lies in the fact that it is tested daily. This operation not only keeps the films in perfect condition, but gives the attendant an accurate indication of the operating condition of the arrester.

"NAVIGATING THE AIR"

The Schenectady Section of the American Institute of Electrical Engineers gave a new distinction to its winter series of lectures on the night of March 19th. The subject selected, "Navigating the Air," was ably treated by Mr. Augustus Post, the well-known aeronaut, who was aide to Alan R. Hawley, pilot of the "St. Louis" in the Gordon-Bennett race at St. Louis. It will be remembered that this balloon remained in the air over thirty-six hours, and traveled seven hundred and eighteen miles. Mr. Post divided his lecture into three heads: History of aeronautics, balloons, and aeroplanes. In a brief review of the historical side of ballooning, Mr. Post referred to the important work done by the balloon at the siege of Paris. Here it was the only medium of communication between the besieged and the outside world, the railroad stations being turned into balloon factories. Sixty-two ascensions were made, and two and a half tons of letters were carried. In describing "What we do in a balloon," Mr. Post said: "The matters of food and clothing became of the utmost importance. We had condensed meat tablets, chocolate and soups in tins, with lime packed around them so that when you put water on the lime it slaked and heated the inner can to the point of boiling. We had to keep a very careful lookout as to where we were going. One problem ever present was that of crossing the Great Lakes. With a steady wind that might easily be done. but if they loomed up when your ballast was nearly exhausted, and in almost calm weather, the drifting slowly over the water would be beset with difficulties and unpleasant risks. Then again one had to be ready for all sorts of changes in temperature. Thermos, bottles, blankets, tin pails, and water proof bags to pack things in were a part of the equipment. There was precious little sleeping done, as observations of various kinds had to be taken every few minutes. As a matter of fact, we did not get any sleep from half-past six Monday morning until ten o'clock Wednesday night. We had an omen of good luck in starting, for a dove alighted on the top of the balloon and sailed away with us for quite a distance. We had supper about midnight. This consisted of hot soup, sandwiches, and hot coffee, eaten with an appetite that was nothing short of superb. Then, wrapped up on our blankets, we were at peace with all the world, and the balloon rode on. No one can quite realize the beauty of a night passed under the great starlit heavens, with the brilliant moonlight making everything as bright as a silver day. As you sail suspended between earth and sky, it seems as if you were in a world of your own; you are far away from the madding crowd and everything is still."

Many of the incidents of the famous Pittsfield ballon ascension, the first ascension of Aero Club members in this country, and those of the more recent St. Louis race, were shown in a series of moving pictures. As in these pictures the various balloons were seen to rise and pass quickly out of sight in the distance, one could readily understand, as Mr. Post put it, that "ballooning made the United States look like a ten-acre lot." Mr. Post then discussed the construction and operation of aeroplanes, or machines heavier than air, and his description of the work of Ludlow, Archdeacon, and Farman was followed by moving pictures of these remarkable aerial vehicles in rapid flight.

The instruments used in taking observations in air travel, loaned for the occasion by Mr. Albert C. Triaca, Director of the International School of Aeronautics, New York, were exhibited, and a collection of photographs of important events in Aeronautics was on view.

In speaking of the part which electricity is destined to play in aeronautics, Mr. Post said that even now, without the use of the electric lamp, and the electric spark for ignition in the motors, flight would be impossible. Indications are already presenting themselves that electricity will be resorted to for the final solution of the problem of the perfectly efficient airship. It may be specially utilized in controlling the various rudders, in equilibriating devices, etc. The transmission of power by wireless may materially simplify the problem.

NOTES

The annual report of the General Electric Company for the fiscal year ending January 31, was issued on May 5th. The gross turn over, nearly $71,000,000, is the largest in the history of the Company, and the profit, $6,948,682, while relatively small, is very encouraging considering the peculiar conditions existing in 1907, viz.: the high cost and inefficient quality of labor, due to the unprecedented demand for workmen; the great reduction in the value of raw materials on hand, due to financial depression, and necessitating a cut of about $2,000,000 in inventory value; the necessity for a large appropriation to cover possible bad debts and for carrying accounts due from customers caught in the depression and temporarily unable to meet their obligations; and the writing off of nearly $4,000,000 out of the year's expenditure of about $6,000,000 for plants, equipment, etc.

The report shows that out of about $35,000,000, the original value of and expenditures for plants and equipment in the last fifteen years, $23,000,000 has been written off, leaving a book value of but $13,000,000. With further writing off unnecessary, and a cash balance of $12,250,000, and surplus profits of $16,500,000, there should be no doubt as as to the payment of dividends.

During the past year $13,000,000 was added to the working capital by the issue of stock and bonds.

In August the Company was entirely freed from floating debt, and had large bank balances with which to successfully meet the panic when money was unprocurable.

Other items of interest are: the taking over of the Stanley G.I. Mfg. Co., of Pittsfield; the purchase of 700 acres of land near Erie, Pa., for the location of another plant; the acquisition and development of a copper mining property, railroad, and smelter in California.

* * *

Mr. Bernard E. Sunny, who for years has been prominently connected with the exploitation and development of the electrical industry in the Middle West, has resigned as Vice-President and Western Manager of the General Electric Co., to accept an appointment as Vice-President of the American Telephone and Telegraph Co., with headquarters in Chicago. He has, however, been elected a Director of the General Electric Co., and therefore his relations with the Company will not be wholly severed.

For ten years prior to 1888, Mr. Sunny was Superintendent of the Chicago Telephone Co., and is therefore thoroughly familiar with the many details of telephone work.

Entering the services of the Thomson-Houston Co. in the above year, he remained with that company until it was consolidated with the General Electric Co., in 1892, since which time he has been intimately associated with the interests of the latter concern.

He is a man of strong personality and purpose, possessing a large number of friends, a rare judgment in business matters, and a marked ability for successfully accomplishing large undertakings.

Mr. J. W. Johnson was appointed Manager of the Chicago office of the General Electric Co. on May 1st. He has been Assistant Manager of the office for several years, and is well qualified by ability and experience to assume his new responsibilities. He is succeeded as Assistant Manager by Mr. F. N. Boyer.

* * *

Mr. John R. McKee, formerly General Manager of the Power & Mining Department of the General Electric Company, has been appointed Chairman of the Sales Committee. Mr. A. R. Bush has been appointed Manager of the Power & Mining Department.

* * *

Mr. A. J. Lighthipe, who has been engineer of the San Francisco Office of the General Electric Co., since 1891, has accepted a position with the Los Angeles Edison Electric Co.

Mr. Lighthipe has been identified with electrical industries since 1879 at which time he entered Mr. Edison's Laboratory after completing his studies at Stevens Institute of Technology. Later in the same year he was sent to London with the loud speaking chalk telephone, and since that time has been associated with the following interests:

International Bell Telephone Co., Antwerp & Verviers, 1880–81; the French Edison Co., 1882; the German Edison Co., 1883; the Brush Electric Co., New York, 1884; Manufacturing at Philadelphia. 1885–86; Electrican, Wilmington City Electric Co., 1886–89; Supt. of Construction, United Edison Mfg. Co., San Francisco, 1890; District Engineer, Edison General Electric Co., San Francisco, 1890–91; Engineer of San Francisco, Office of General Electric Co., 1900.

* * *

Mr. Thomas Vincent Bolan of the Philadelphia Office of the General Electric Co., died at his home in Philadelphia on February 18th.

Mr. Bolan was born in London, England, on October 31, 1865. He was a graduate of Georgetown College and of the Massachusetts Institute of Technology, where he pursued a course in Electrical Engineering.

After graduation, he entered the employ of the General Electric Company, one of his early works being the installation of the Providence, R. I. trolley system.

Later, he specialized in cotton mill work and had charge of several important cotton mill installations in the South. He rose rapidly in his profession and at his death was regarded as one of the best engineers in his line.

For the past ten years he has been in charge of mill power work at the Company's Philadelphia Office. He was an associate member of the American Institute of Electrical Engineers.

* * *

Mr. Conway Robinson, with the A.C. Engineering Department of the General Electric Co., was married on April 21st., to Miss Jane Stockton Dorsey, of Baltimore, Md.

Mr. Robinson has been appointed Manager of the Works of the Tokio Electric Co., Tokio, Japan.

* * *

Mr. Eugen Eichel, formerly connected with the Engineering Department of the General Electric Company, has opened an office in Berlin as consulting engineer.

Everything Electrical for Mine Equipment

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Four and one half ton General Electric mining locomotive with train of ore cars coming out of cross-cut tunnel Bunker Hill and Sullivan Co., Kellog, Idaho.

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lighting
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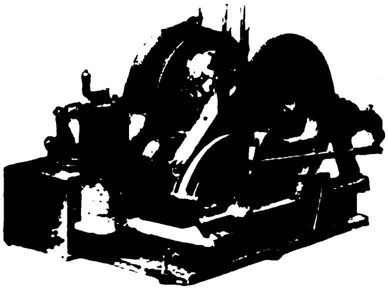
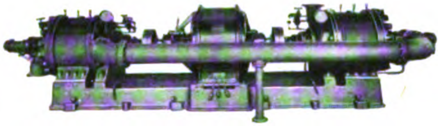
Curtis steam turbine generators, motor driven fans, pumps, hoists and electric locomotives make profitable operation possible

Flywheel motor-generator set for operating mine hoist motors.



Mine hoist operated by General Electric Motor.



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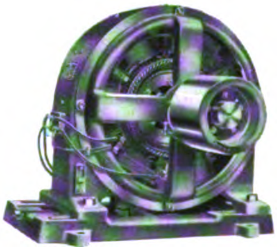

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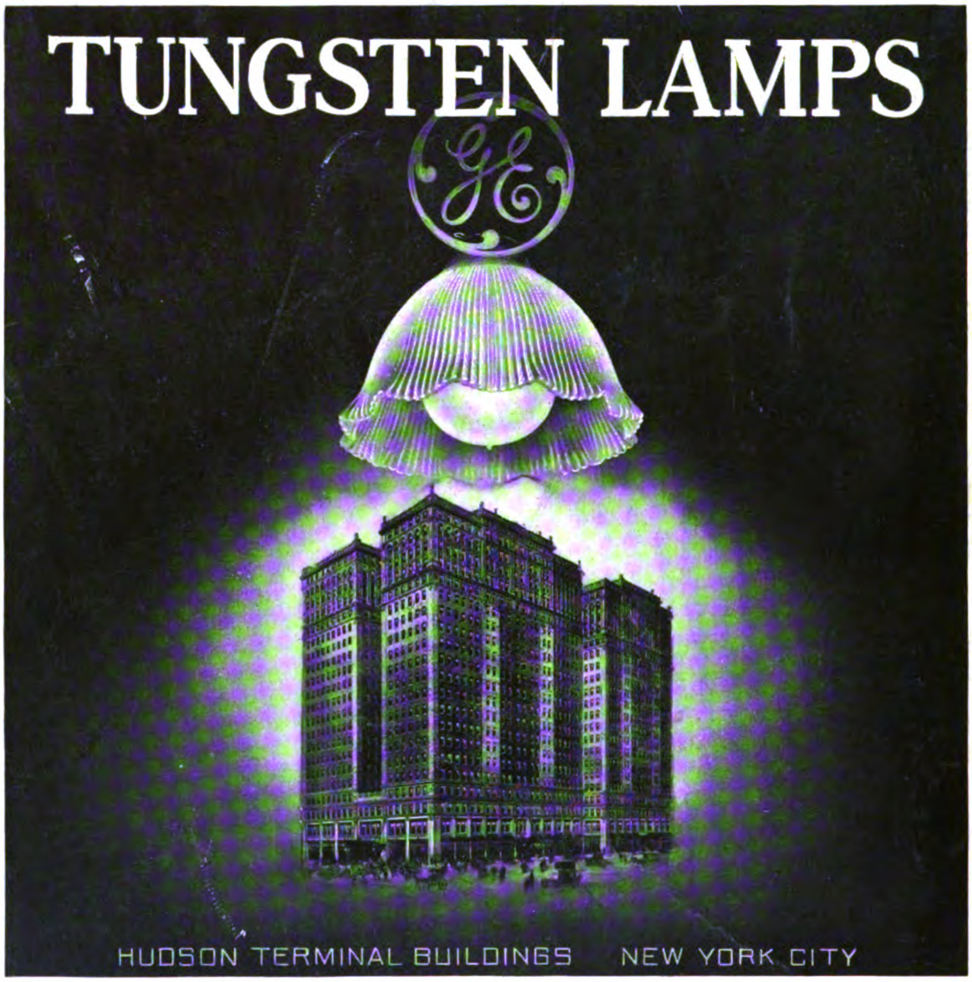
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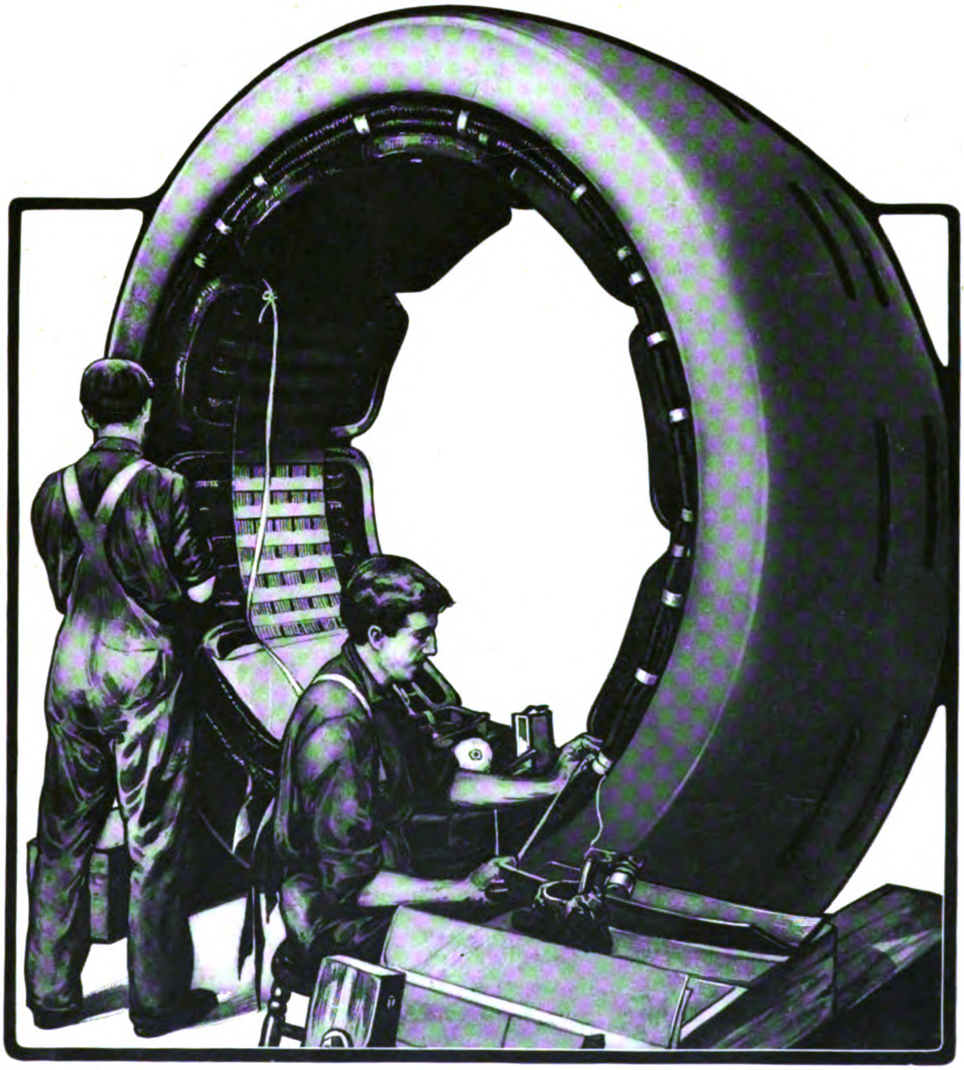

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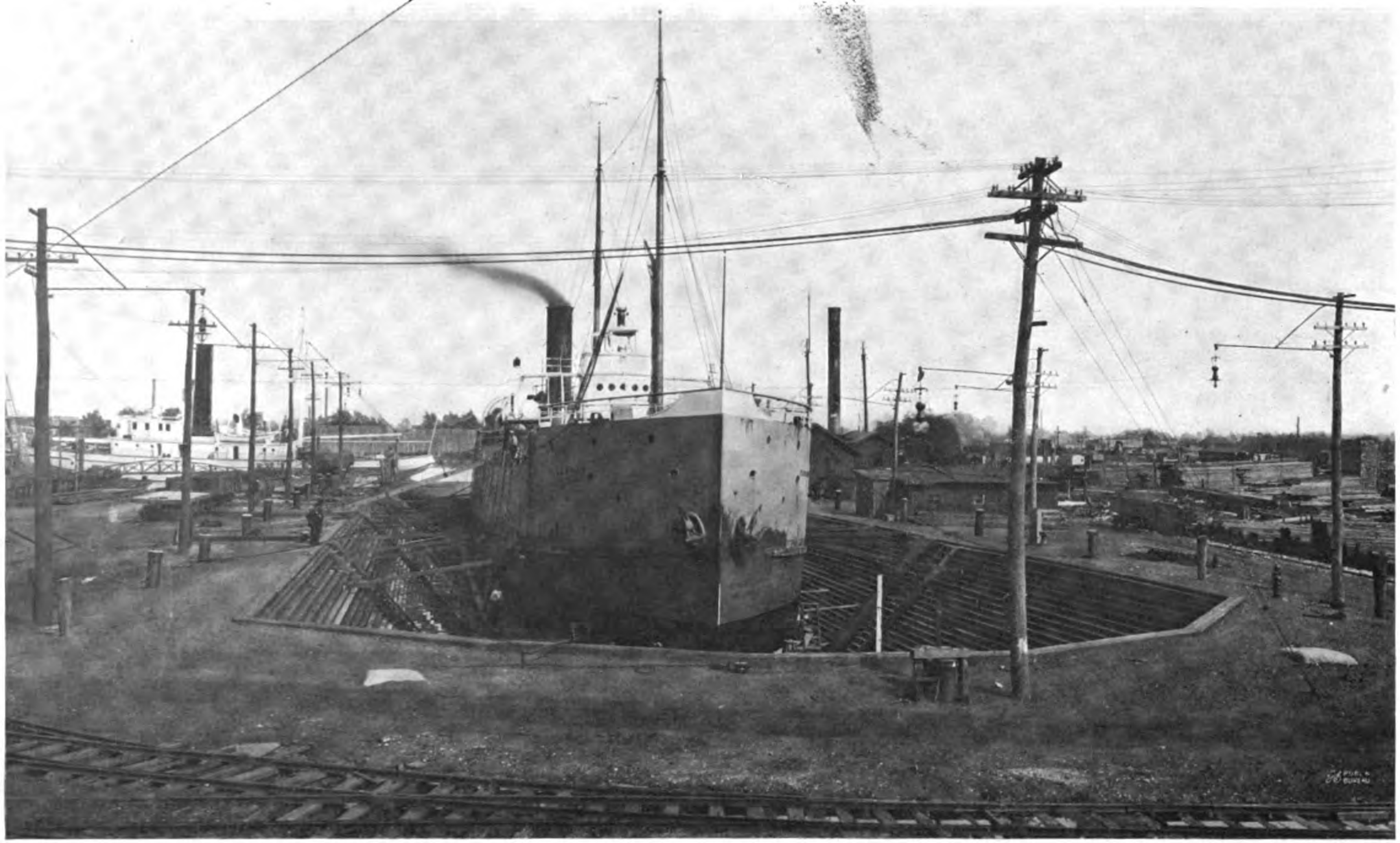


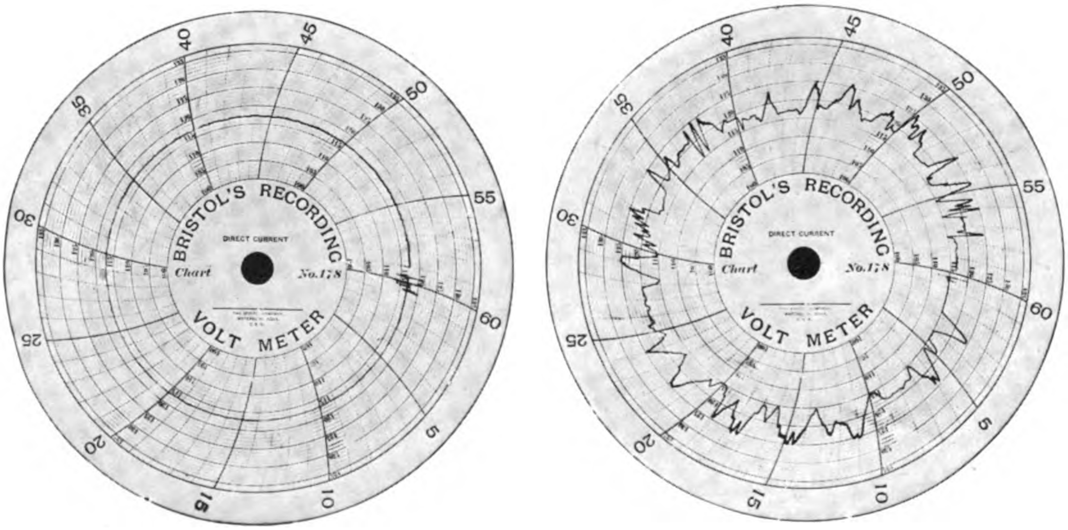
Dry Dock of the Harlan and Hollingsworth Corporation, Wilmington, Del.

(See page 35)

GENERAL ELECTRIC REVIEW

AUTOMATIC FEEDER REGULATORS *

The generation of direct current for purposes of general distribution is rapidly becoming a thing of the past and is continually being superseded by its flexible competitor, the modern alternating current system. The tendency is to concentrate the source of energy in a few large units, instead of a number of small generators so arranged as to supply individual circuits of small capacities. In the case of the large generating units, the energy current is distributed to the consumers by means of separate and independent feeders; and the object of this paper is to show that it is just as necessary to regulate these individual feeders, as it would be to regulate the generators in the case of a large number of small units, if good regulation of the entire system is essential.



Regulator Side **Generator Side**

Fig. 1. Voltmeter Curves Showing Voltage Regulation of Type BR Regulator

For instance, different feeders are of various capacities and lengths, and may serve localities of widely varying local conditions; thus, one feeder might serve a residence section, one a manufacturing section and another a business section, each section very probably having its "peak load," or maximum demand, at a different period. These varying conditions all tend to produce unequal voltages at the center of distribution with the consequent poor regulation which is such a menace to any electrical system. This fact emphasizes the need of individual feeder regulation. The necessity for good regulation and the beneficial results accruing therefrom are becoming more fully appreciated by all practical central station men; and this regulation is not only the measure by which the customer judges the excellence of a lighting system, but determines in no small degree the economy with which that system operates.

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* Paper read by Mr. P. D. Wagoner at a dinner of the New England Electric Light Association, Boston, Mass.

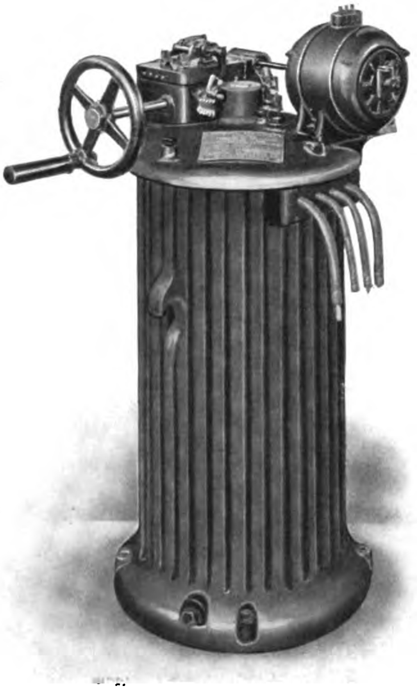


Fig. 2. 8 1/4 Kw. Single-Phase Induction Regulator, Oil Immersed Self-Cooled Type

In offering any piece of apparatus to a central station manager, you have to show him whereby he will profit by the addition of the new apparatus to his system, which might *apparently* be operating at its maximum efficiency as it stands.

The success of *any* business, whether it be that of a central station or a dry goods establishment, depends primarily upon the satisfaction which it gives its customers. In the case of lighting service, the customer judges the merits of the system by the uniformity, brilliancy and reliability of his lights. Excellence in all of these qualities can only be attained by means of a steady voltage.

By referring to a curve plotted between voltage and candle-power of a 16 c.p. carbon filament lamp, it will be seen that a reduction of only 2 per cent. in voltage at the terminals will cause a decrease in candle-power of 11 per cent. It may be said, as a point of physiological interest, that a flickering or a change of intensity in a light source, whether very gradual or of medium periodicity, is extremely injurious to the eyes—a fact which is too often overlooked. Another point of interest is that the eye is an extremely sensitive photometer when it comes to detecting slight variations in the candle-power of the source of light.

The subject of lamp renewals is of no small consequence, and in the majority of cases this item becomes of serious magnitude. Here, again, as in the case just cited, the variation of potential at the lamp terminals plays an important part. In the ordinary carbon filament lamp, if the voltage is increased only 1 per cent. above normal, the life of the lamp will be reduced 18 per cent., or to 82 per cent.

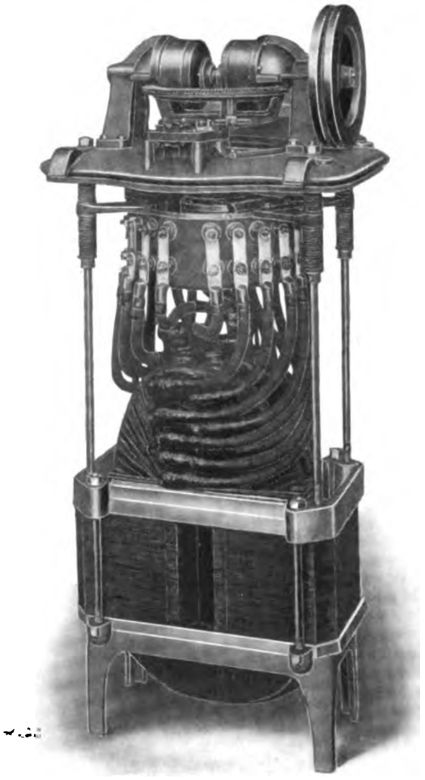


Fig. 3. Type BR Regulator Removed from Case

of its normal life, while the candle-power will be increased only 6 per cent. Should the voltage be increased 5 per cent. above normal, the life of the lamp would be reduced 64 per cent. or to 36 per cent. of its normal life.

The increased sale of energy to customers is another point in favor of a maintained constant potential. It is always at the peak of the load, the time when the major portion of the energy is sold, that the voltage is below normal, due to increased line losses. This is the most important time at which the central station should maintain a steady voltage. It is evident that this is true, and that the delivered energy falls off rapidly with a decrease in potential. This not only means that the customer does not receive the light nor the power which he is expecting, but that the central station loses the sale of an amount of energy equal to the difference between the energy demanded (or expected) and the energy actually consumed at the voltage supplied. With feeders which are not properly regulated this can easily amount to a reduction of 15 or 20 per cent. in the sale of energy during the period of maximum demand—*an absolute loss of revenue with no compensating advantages whatever.*

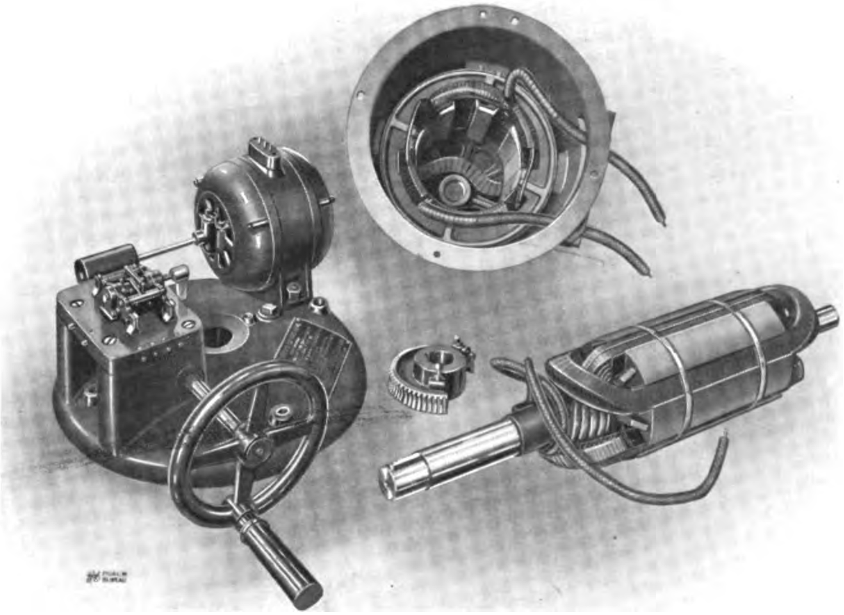


Fig. 4. Mechanism of 8 1/4 Kw. Single-Phase Induction Regulator

In many cases, the rapid growth of a section supplied by a given feeder prevents the most efficient operation, and very often the station manager is confronted by the serious condition that no more power can be delivered over such a feeder until an additional line is strung to care for the extra load. At such a time, the feeder regulator may be used to great advantage, to tide over matters until a general expansion of the system can be accomplished.

In the previous paragraphs greater stress has been laid on lighting systems, but the same applies equally well in the case of a motor load, since it must be remembered that a motor operates at its maximum efficiency when run at its normal voltage for any given load. In the case of a reduced voltage, the customer is paying for increased losses due to the heavier currents; and in turn, the central station is losing a proportionate amount of energy in the feeders.

The question of a reduction in station attendants should not be overlooked while speaking of the automatic feeder regulator. The introduction of a reliable automatic regulator will not only eliminate the personal errors, negligence or lack of attention (maybe due to lack of time) of the assistants required in the case of manually-operated apparatus, but will permit a reduction in the running expense of the station. The automatic regulator is always "on the job."

Before passing to the description of the feeder regulators, it may be said that individual regulation of generators is successfully obtained by the well-known TA regulator.

The General Electric Co. has designed and developed two types of feeder regulators; one known as the induction type, and the other as the switch type. Both are variable ratio transformers connected as compensators in principle. The induction type of regulator, which is shown in Fig. 2, is designed for single and polyphase service, and may be operated either by hand, motor (or remote control), or automatic control. The switch type, which is shown in Fig. 3, is designed only for single-phase service, and it also may be hand, motor, or automatically controlled. Since this paper deals primarily with automatic regulators, the hand and motor operated types will not be described; but it might be said, however, that they conform to the same principles of design as the automatic regulator, the only difference being in the mechanism for automatic operation.

The automatic feeder regulator seems to be a piece of apparatus which speaks for itself; but still, a few words in its behalf will not be amiss.

Induction Type

For the sake of clearness, the construction of the single-phase induction regulator will be more fully described. In this type there are two separate and distinct windings arranged on concentric laminated iron cores; the primary winding, with its core, being mounted on a vertical shaft which can be partially rotated; and the secondary being wound in the slots of the stationary core, and resembling very closely the stator winding of an induction motor. The construction is very clearly shown by Fig. 4.

In the single-phase regulator, the shunt, or primary winding, is connected by means of flexible cables directly across the feeder to be regulated, and the secondary winding is connected in series with the feeder, as is shown in Fig. 6. The product of the amperes and volts on the generator side is always equal to the product of the amperes and volts on the feeder side, except for the very small (practically negligible) loss in the regulator itself. This principle applies to both the single and polyphase types of regulators. A movement of the primary core in one direction produces a boosting effect, and in the opposite direction, a lowering effect. This is due to the *alteration* of the magnetic flux produced by the relative movement of the primary and secondary windings.

The voltage of the single-phase regulator is strictly in phase with that of the feeder, and is, therefore, directly added to or subtracted from the feeder voltage. The polyphase regulator has an alternating revolving flux, similar to that of a polyphase induction motor, and the same voltage is at all times induced in the secondary winding. This voltage, however, is applied at different phase angles, by rotating the primary winding, thus changing the phase displacement and giving the desired voltage variation, boosting or lowering, as the case may be.

In addition to the shunt or active winding, the primary, or movable core, has a short-circuited winding mounted thereon, which, in the case of the single-phase type, is arranged at right angles to the shunt winding. The object of this short-circuited winding is to decrease the reactance of the regulator. Its action is as follows:

As the primary and short-circuited windings are both on the movable core and permanently fixed at right angles to each other, the flux generated by the primary passes on either side of the short-circuited coil, and is therefore not affected by it in any way whatever; for as long as there is no flux passing through this coil, there is no current flowing in it. This condition, however, is true *only* when the primary is in either the position of maximum boost or maximum lower, with current flowing in the series winding; and in any position of the armature (or primary), with *no* current flowing in the secondary.

If the primary core were not provided with a short-circuited winding, and were rotated from either maximum position, so as to reduce the primary flux passing through the secondary, and if the line current remained constant, a gradually increasing potential would be required to force the current through the series windings, and a correspondingly increasing flux would be generated in the stator iron. This reactance voltage would become a maximum with the armature in the neutral position, due to the fact that in this position the shunt coils are at right angles to the series coils and therefore entirely out of inductive relation to them. The current in the secondary, therefore, would act as a magnetizing current, and a considerable part of the line voltage would have to be used to force the current through these coils. The voltage so absorbed would be at right angles to the line voltage, and the result would be a poor power factor on the feeder.

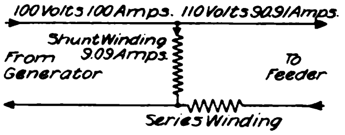


Fig. 5. Regulator Boosting

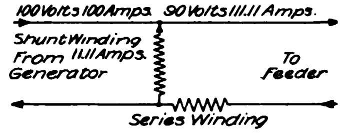


Fig. 6. Regulator Lowering

However, the short-circuited coil on the armature, which is in a direct inductive relation to the series coils when the armature is in the neutral position, acts as a short circuit on the secondary winding, and thereby reduces the voltage necessary to force full load current through this winding, to only a trifle more than that represented by the resistance drop across the secondary and short-circuited windings. This short-circuiting effect of the secondary is gradual, from zero in the maximum boosting position of the regulator to maximum value in the neutral position, so that by the combined effect of the primary and short-circuited coils, the reactance of the secondary is kept to within reasonable limits, and consequently produces no appreciable effect on the line.

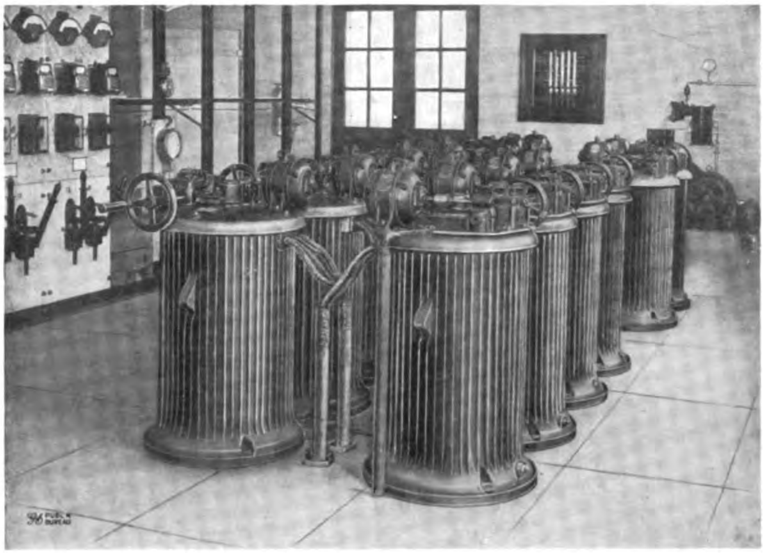


Fig. 7. Group of IR Regulators as Installed by Philadelphia Electric Company

The operation of the short-circuited coil does not increase the losses in the regulator, but rather tends to keep them constant for a given secondary current.

As can readily be seen from the foregoing description, the regulation, whether boosting or lowering, takes place over a smooth and continuous gradient, *and not in steps*.

Beginning with the hand-operated regulator, we simply have a handwheel suitably geared to the shaft of the movable armature. To convert this into the motor-operated (or remote control) type, a small induction motor of high torque is geared to the handwheel mechanism, and the maximum movement of the armature in either direction is checked by a limit switch. This switch prevents a further movement in the direction of the armature travel by open-circuiting the motor for that particular direction, but leaves it free to be operated in an opposite direction by reversing the control motor switch.

In turn, the motor-operated regulator is converted into an automatic regulator by the addition of a contact-making voltmeter. This device is placed directly across the feeder to be regulated, through a suitable potential transformer, and should the voltage deviate from that at which the device is set to operate, it will close an auxiliary circuit and cause the operating motor to adjust the position of the regulator armature to give the predetermined voltage. When this value is reached, the relay of the voltmeter opens the motor circuit until the voltage again reaches a low or abnormal value, when the operation is repeated.

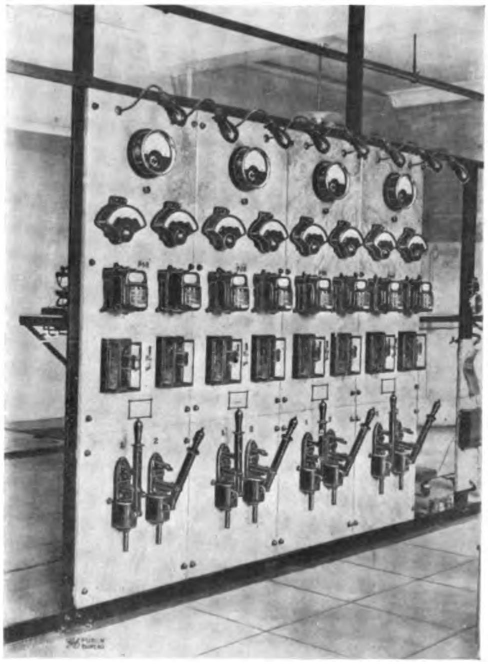


Fig. 8. Feeder Panels, Showing Contact-Making Voltmeters, Philadelphia Electric Company

The contact-making voltmeter is so constructed that it can be adjusted to maintain the potential within 1 per cent. of normal at some distant point on the feeder. This is accomplished by connecting a suitable compensating winding in series with the solenoid, the compensating winding being furnished with a multi-point switch so that different adjustments can be made. This method of compensation takes care of the average conditions of ohmic and inductive drop.

When the contact-making voltmeter is utilized to cause automatic operation, a brake magnet is mounted on the cover of the regulator, and operates directly on the motor shaft. This brake, being normally set in a braking position, only releases when energized from the same circuit that operates the motor, so that when the motor is thrown in circuit, the brake releases, and *vice versa*. This scheme effectually prevents all tendency of the regulator to "hunt."

In sizes up to 50 kw., the cooling of the induction type of regulator is usually effected by immersing it in a suitable corrugated cast-iron tank filled with oil. The larger sizes are generally cooled by either air, or oil and water.

The power factor of this type of regulator is not quite so good as that of the switch type, but the effect of the lower power factor of the regulator on the total power factor of the system is, in most cases, negligible, usually being only a small fraction of 1 per cent.

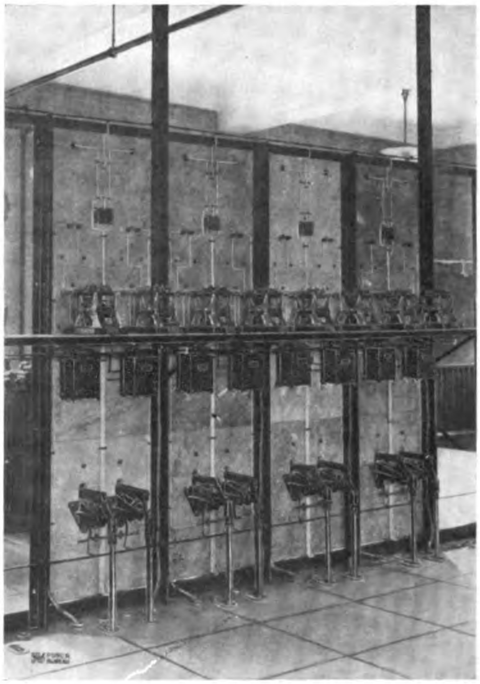
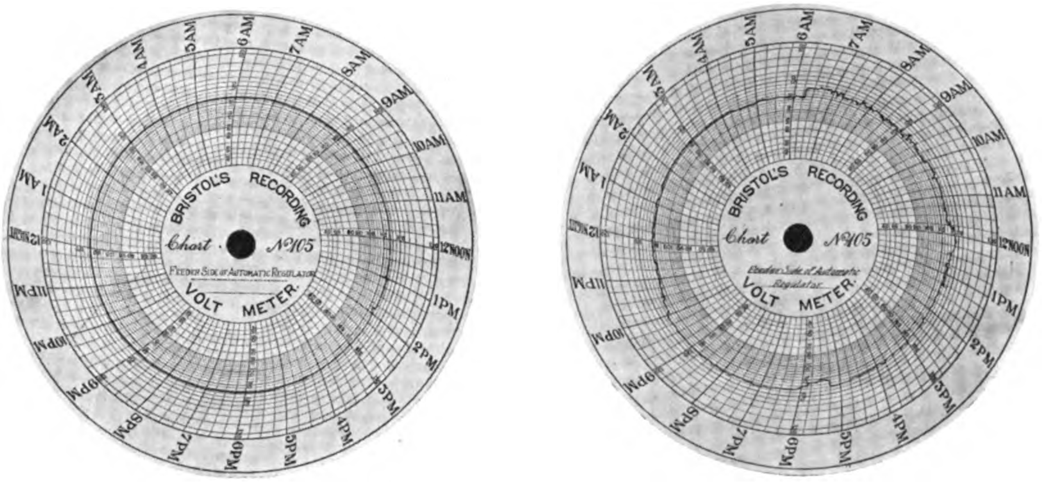


Fig. 9. Rear of Feeder Panels, Showing Relay Switches, Philadelphia Electric Company

The efficiency varies from 92 per cent. to 95 per cent. in the single-phase sizes of 5½ to 22 kw., and from 88 per cent. to 92 per cent. in the polyphase regulators of corresponding sizes. *The efficiency is based on the kilowatt capacity of the regulator*, and *not* of the feeder, and therefore it must be remembered that the reduction in total efficiency caused by the addition of regulators is very slight indeed; in most cases it is only a small fraction of 1 per cent. of the total.

The question might be asked, How much loss is entailed by the automatic auxiliary apparatus? As a matter of fact, the contact-making voltmeter is the only one of the auxiliary devices that is continually in circuit, and this consumes only about 88 watts at 110 volts—just a trifle more than an ordinary 16 c.p. incandescent lamp. The relay magnet and the brake magnet operate only at intervals of changing voltage, and take approximately 27 and 130 watts respectively. It is thus seen that the decrease in efficiency caused by the auxiliary apparatus of an automatic induction regulator is insignificant.



Regulator Side **Generator Side**

Fig. 10. Voltmeter Curves Showing Voltage Regulation of Type IR Regulator, Philadelphia Electric Company

This type of regulator is particularly well adapted for use on feeders of large capacities where the load fluctuations are gradual. The inertia of the moving element is such that it will not permit an extremely rapid movement from maximum boost to maximum lower, the time of this cycle varying from 1 to 1¾ minutes depending on its size. For regulating feeders of small capacities, it will thus be seen that a regulator having light moving elements would be essential, and for this purpose the General Electric Co. has developed the switch type of regulator.

Before leaving the subject of the induction type, it might be said that it is used quite extensively in connection with rotary converters, and has proved to be of great value in the regulation of the direct current voltage.

Switch Type of Feeder Regulator

The switch type of feeder regulator is designed for single-phase service only, and is made for hand, motor or automatic control.

The type letters CR are used to designate the General Electric Co.'s regulator that is adapted to either hand or motor operation, and the letters BR designate the automatically-operated regulator. Only the automatic, or BR type, will be dealt with in the following description.

This regulator is of radically different construction from the induction type which has just been described, the electrical principle, however, being the same; but instead of using a movable core and windings which have considerable weight and inertia, the light contact fingers of a dial switch constitute the moving element. The construction of the core and windings is of the shell-type design, and consists of two windings. One of the windings is connected in shunt with the feeder, and the other winding, which is provided with a number of taps, is connected in series with the feeder to be regulated.

The taps from the series coil are connected by means of flexible cables to a multi-contact dial switch. This switch consists of three separate parts, namely: the stationary contacts, which are arranged on the inside of a cylindrical cast-iron case; the stationary collector rings, arranged in the center and concentric with the cast-iron case; and the light moving part which carries the contact fingers. This third part consists of a metal carrier which has mounted on it the contact fingers, the fingers all being thoroughly insulated from each other. These fingers bridge the space between the stationary contacts and the ten stationary collector rings, and are so arranged that several of the fingers are touching the same contact at the same time. There is, however, a suitable resistance connected between adjacent fingers, otherwise there would be a short circuit between the various taps. By thus having a multiple path of contact, the circuit is never broken, and therefore it will be seen that no sparking can possibly occur.

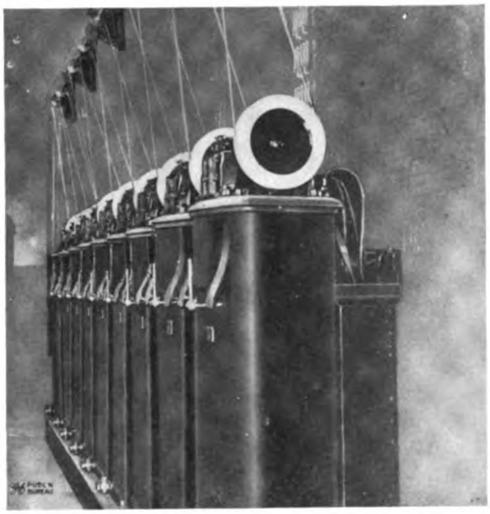


Fig. 11. Automatic BR Regulators Installed at Toledo Railway & Lighting Company

The operation of this switch is very simple, and is as follows: The movable switch is connected by means of a central shaft to a bevel gear on the top of the case. On opposite sides of this gear, two magnetic clutches are mounted on a horizontal shaft, each being provided with a pinion which meshes with the gear on the vertical shaft. A small fly-wheel keyed to this shaft is belted to an auxiliary motor and kept in continual rotation at 100 r.p.m. A contact-making voltmeter, as previously described, is used to energize either one or the other of the magnetic clutches which in turn causes its respective pinion to engage the bevel gear which rotates the multiple switch. The two clutches being mounted on opposite sides of the gear, no reversing relay is necessary. As in the case of the induction regulator, this type is furnished with a limit switch which checks the movement when either extreme position is reached. Fig. 3 shows very clearly the internal construction of the BR regulator. The core, as shown in this figure, is rigidly secured to the cast-iron cover by means of four vertical bolts, and it will be noted that this construction very readily permits the entire removal of the regulator from the case containing the cooling oil. From a standpoint of inspection, this feature can well be appreciated.

The power factor of the BR regulator is so nearly 100 per cent. that it need not be taken into account at all. The efficiency varies somewhat with the size, and with the position of the contact fingers; that is, it is at maximum when all of the taps are in circuit, and the average may be taken as about 92 per cent. As in the case of the induction regulator, it must be remembered that the efficiency of the regulator is based upon the kilowatt capacity of the *regulator itself*.

The clutch magnets on the BR regulator, which are only in circuit intermittently, require about 55 watts at 110 volts D.C. The contact-making voltmeter requires continuously about 88 watts.

With individual regulators a ⅛ h.p. motor is usually belted direct to the fly-wheel, and in cases where groups of BR regulators are operated, it is best to belt the motor to a line shaft from which the individual fly-wheels are driven, as shown in Fig. 11. The losses involved by the use of this auxiliary motor are so small as to be negligible.

The feeder for which this type of regulator is best adapted is one which is subject to very rapid fluctuations, since the total travel of the switch, from maximum boost to maximum lower, can be accomplished in the extremely short period of 5 seconds. By reference to Figs. 1 and 10, a clear conception may be had of the value of an automatic regulator when working on a feeder operating under such conditions as those shown by the generator charts.

In conclusion, it might be said that a valuable characteristic of each of the regulators above described is that the variation is entirely independent of the load; that is, the total range in voltage, from maximum boost to maximum lower, can be effected without *any* current flowing through the series coils of the regulator.

CONTINUITY OF EDUCATION*

By Frederick P. Fish

The wisest of kings has told us that:—

"To every thing there is a season,
And a time to every purpose under the heaven."

The graduation period of our universities is above all a season for congratulations and best wishes to those who have completed their preliminary training and are about to enter upon the strenuous work of after life. These I cordially tender. But it is also a time at which an hour may well be spared for reflecting upon the nature and character of the change in effort and aspiration that comes with the completion of the courses in the university; that the relation of the future to the past, of the new life to the old, may be more clearly apprehended. I shall touch upon but one phase of the matter, although many are well worthy of consideration, and shall only hope to emphasize a thought that is undoubtedly familiar to you all. It can not be necessary to do much more than remind you that your education has by no means been completed by your successful mastery of the admirable courses of instruction offered to you by this great university, but that it will continue throughout your lives. While I shall enlarge to some extent on this subject, my chief effort will be to impress upon you, that exactly as the extent to which each one of you has profited by his training in the Columbia Schools of Applied Science has depended not merely upon his individual capacity but even more upon the point of view and spirit with which he has approached his work, so in the future the degree and character of the education which each man will receive and the profit and pleasure of it to him, are matters largely within his own control.

First, however, I must say something as to education and its aims and purposes, as I gather them from observation and from history, for views as to the continuity of education can not be estimated at their true value unless there is a definite understanding of the nature, characteristics and purposes of the education that is to be continued.

It is generally conceded that a prime function of education is to train the individual, that he may be able to deal with the affairs of life, complicated and variable as they are, with intelligence, honesty, efficiency and sincerity; to fit him to adjust and readjust his relations to other men and to affairs as occasion may require; to excite his sympathy with all that is noble and beautiful in life and in nature; to develop his moral and intellectual powers so as to make him, to as great an extent as possible, effective, useful to himself and to others, and as far as may be, a happy and successful man.

It is interesting to find how early this broad idea of the function of education was recognized. Three thousand years ago it was stated with considerable definiteness by the great master who recorded with amazing vividness and power, as incident to his wonderful story of the Trojan War, the views of life then current. In the ninth book of Homer's Iliad, the old man Phœnix reminds his former pupil, the swift-footed Achilles, son of Peleus, of the duties imposed upon him as tutor when he was placed in charge of the young hero's education. These are his words:

> "To thee did the young knight, Peleus, send me the day he sent thee to Agamemnon forth from Phthia, a stripling yet unskilled in equal war and in debate, wherein men are pre-eminent. Therefore sent he me, to teach thee all these things, to be both a speaker of words and a doer of deeds."

An education which trains a man to be a speaker of words and a doer of deeds must be most comprehensive. It involves every form of intellectual, moral, æsthetic and physical training. Such was constantly the Greek ideal, which was so well attained in the little city of Athens and the few square miles of surrounding country. Although the Greek race failed politically, the failure was not due to its theories of education, nor altogether to the fact that at the climax of its greatness, it departed from those theories by allowing the "speaking of words" to assume a far more important place in its thoughts and aspirations than the "doing of deeds." The effects of the Greek method of training have been lasting and of prime importance in the history of the world.

Looked at merely from this point of view, the things taught are relatively of little importance. It is certainly of value to have in mind as many items of information as possible, whether of fact or theory, but the great thing is training, and a man is well educated, even if most that he has learned is forgotten, provided the intellectual and moral faculties have been so developed as to give a right view of life, and to insure a firm grasp on each situation as it arises, with the power of accurate analysis and synthesis and the capacity for sound decision and of strong, definite and discreet action in pursuance of that decision.

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* Address to the Graduating Class of the Schools of Mines, Engineering and Chemistry, Columbia University, May 26, 1908

There has always been however, another type of education which, as a practical matter, was even of greater importance than that to which attention has just been called. It is the learning of things for the sake of applying the knowledge so acquired in the practical affairs of life. From the days "when Adam delved and Eve span," the very existence of the human race, and everything growing out of the presence of that race on the earth, have required that the vast majority of its members should work. Some of them have worked with their hands; some with their brain; and some with both hands and brain. The work has seemed to be primarily in the interest of the individual, that he might acquire the necessities and luxuries of life. In reality, however, it has been even more in the interest of the race, that it might thrive and prosper.

Everyone who has worked has of necessity received a real education for the work he had to do. The day laborer has to be educated to use the pick and shovel; the housewife to do the work of the family; the farmer, the mechanic, the musician, the hunter and the fisherman, the tradesman, the sailor and the soldier have all been educated men in a true sense, even if they never saw a book or attended a school. Each has learned and has been taught to do the particular thing in the world's work that by his own will or by chance has been assigned to him.

This same kind of education, that is, the learning of special things for vocational purposes, is equally essential to the lawyer, the judge, the scientist, the statesman, the artist, the business man, the physician, the engineer, and the chemist. Without it, they can not play their parts.

Only within recent years has it been generally recognized that special teaching institutions were required in the interest of education for the vocations. It is true that schools of law, theology and medicine existed in the Middle Ages, but it is probable that by far the greater number of lawyers and doctors have learned their law and their medicine otherwise than by systematic schooling. Such was certainly the case, even in this country, up to a few years ago.

There were until very recently substantially no schools for the other trades and professions. The special education, fitting him for his work, of the engineer, the farmer, the business man and the chemist, like that of the tradesman, the mechanic, the artist and the housekeeper, was based almost altogether upon imitation. Exactly as the primeval hunter learned from older and more experienced men the habits of animals and how to stalk or snare them, and as the farmer's son absorbed his father's methods of tilling the soil and of sowing seed and caring for and gathering the crop, so the engineer, chemist, business man and manufacturer learned their respective arts by associating with their elders, and absorbing while in active work the results of the training and experience of former generations.

There was but little recognition of the need of any systematic school education for vocations.

It is a far cry from Homer of three thousand years ago to John Locke of the 17th century, but the latter's thought had not progressed far beyond that of Phœnix and of Peleus. In a well-known passage in his "Conduct of the Understanding," Locke says:

> "The business of education is not to make the young perfect in any one of the sciences, but so to open and dispose their minds as may best make them capable of any, when they shall apply themselves to it . . . It is therefore to give them this freedom that I think they should be made to look into all sorts of knowledge and exercise their understanding in so wide a variety of stock of knowledge. But I do not propose it as a variety and stock of knowledge but a variety and freedom of thinking, as an increase of the powers and activities of the mind, not as an enlargement of its possessions."

Locke thus limited the field of systematic education to the effort so to develop the student's faculties that he could afterward take up as his life's work any vocation that attracted him, and by reason of his intellectual training absorb, largely by imitation and association, the principles of the art to which he was to devote himself and the facts relating to it, without the necessity for a school education especially directed to that end.

Whether John Locke was right in his day and generation need not be discussed. There have been vast changes in industrial and social conditions since then. A theory which was sound even sixty years ago, may well require revision in view of the extraordinary developments of the past half century. It does not seem exaggeration to say that our industrial and business conditions have changed more since the beginning of our Civil War than in all recorded history prior to that date. The change in social conditions has also been most striking. The effect upon our society of the elimination of space and time that has followed the application of electricity to the useful arts and the recent development of our transportation systems, together with the striking modifications of the past few years, has been most far reaching. Among other things, it can easily be shown that our great organizations of capital and labor, with the conflicts, trials and uncertainties resulting from them, have developed by an inevitable evolution from these new conditions.

For reasons that are obvious but which I have no time to present, it is to-day possible for neither engineers or chemists on the one hand, nor for artisans on the other, to get an adequate vocational training in the old way. Systematic education is required. The advanced technical schools of this country, of which those of Columbia University are an admirable type, are caring for the engineers and chemists. They form a recognized and important part of our educational system. Every good citizen who has the welfare of his fellow citizens at heart should co-operate in the effort to secure everywhere adequate industrial schools for the training of mechanics and artisans. There is no one thing upon which our prosperity more largely depends.

While there is no question as to the absolute necessity of the university technical school, no doubt as to the great value to the engineer and chemist of a systematic training in applied science as preliminary to actual work, it can not be denied that the older views of education to which I have referred, were well founded. The criticism to be made upon them is that they were narrow and incomplete. All agree that no scheme of education is effective which does not develop character, breadth of view, and a general capacity for dealing with men and things outside of as well as within the field of specific professional work. But it is equally clear that the pursuit of exact knowledge of the kind that will be useful in professional work, ought to be effective in promoting general culture. There can be no magic in one study rather than in another. Is not a training in mathematics sure to develop the logical faculty? What could stimulate the imagination more than the wonders of electricity? Can any subject cultivate the habit of accuracy, of observation and of thought to a greater degree than the applied sciences? Is it possible to study the applications of the laws of nature, which are absolute truths, without a strengthening of the moral as well as of the intellectual fibre? Can there be a greater inspiration to industry, integrity, and clearness of vision than a consideration of the wonderful achievements of the philosophers, investigators and inventors who have made our applied science what it is?

In so far as there is any danger that a professional training in the scientific schools of the university will not result in the "state of mind" which is the fruit of liberal training, it must be for a reason outside of the subject matter taught.

Surely, every man needs a liberal education to as large an extent as possible. He also needs training in his special work. It seems certain that each of these fields of preliminary training is a necessary supplement to the other.

The great problem of university education is, in my opinion, so to correlate work in the two fields that each will be cultivated so as to promote good results in the other. The liberal training must not merely seek to satisfy general or even ideal conditions. It must aim to fit the student to play a creditable part in the affairs of after life, where he must work for a livelihood and for success. The vocational education must not be satisfied with the production of an efficient specialist—it must seek to produce as well a broadly educated and well rounded man.

The time is surely coming when our entire system of education will be based upon the idea which I have so inadequately presented; and it is only when this idea is fully accepted and, as far as possible, realized in practice, that our school and university training, as a whole, will be organized so as to fit the needs of society.

I have spoken of education in the narrow sense of school and university training only to make clear what education is, and its aims and purposes, as I understand them. Whatever views on the subject may be entertained (and I do not advance my own as either new or adequate), it is clear that the education of the individual is a matter not of a few years but of a lifetime. It begins with the first effort of will and intelligence, and ends only when the faculties become so impaired that further development is impossible.

At the present time, practically all the people of European stock and, to a less degree, the more civilized races in other parts of the world, have the benefit of school education. It is, however, no exaggeration to state that the bulk of the human race has had no such advantage. Comparatively few of all the men that have lived upon the earth have received any school instruction, and by far the greater part of the schooling that has been given was of a character largely useless and ineffective according to our modern standards.

And yet, what great things have been accomplished by those whose education was practically only that of individual experience, association with others, and imitation! What great men have been developed without the aid of schools!

To go back to the earliest times of recorded history, we find in Assyria, Babylon, and Egypt a real civilization, in which for generation after generation, men of genius were developed and most extraordinary things done, said and recorded; although there is no reason to suppose that even in the most prosperous periods of these nations, there was any definite education except among the priestly class, with whom it was chiefly an incident to their professional functions. Outside of their triumphs in war and conquest, the achievements of those ancient peoples in engineering, in architecture, in science, in law, in business, in literature and in art, fill us with amazement. Writing had been invented, and the records that have come down to us on stone or burnt clay or papyrus, show a condition of industrial, social and political development which is marvelous to the last degree. We find recorded elaborate codes of law; definite history, with proper attention to chronology; philosophical and theological discussions; business documents of the most elaborate character; treaties and political proclamations. These records show a capacity for thought, intelligence and action practically equal, as far as one can see, to that of our own time. Not only were the simpler arts like agriculture and the textile industries, advanced to a point approximating that which had been reached a century or so ago, but architecture, engineering, sculpture and other fine arts, ship-building, navigation and astronomy had developed to a surprising extent.

The next race prominent in the world's history was the Greek, whose system of education, confined as it was to relatively few members of the community, has in it hardly a feature that commends itself to our modern practice. Gymnastics and music, the recitation of poetry and the study of rudiments of mathematics, studied not so much for the acquisition of knowledge as with the view of securing an harmonious physical, intellectual and æsthetic development, were the important elements in the education of the boy in the Golden Age of Greece. The utmost attention, however, was paid to insure his intimate association in affairs, and full opportunity for personal contact with other men in all the important relations of life. We all know what the Greeks accomplished and to what extent the subsequent history of thought and intelligence has been based upon their work.

Next came the Romans, the great organizers and law-makers of the world. It can not be said that their achievements, the influence of which has been to so large an extent a controlling factor in the history of the past 2000 years, were based to any substantial degree upon their school education. While the German races, who succeeded them, were not mere barbarian conquerors, but had rules of law and standards of personal and national character and conduct which have influenced all subsequent development; it was probably many years after their settlement in Western Europe before any of them had such a thing as a school system.

Can it be said that school education was to any appreciable extent responsible for the great men and the great things of the Renaissance? I have often wished that some competent investigator would write a monograph on the education of Leonardo da Vinci; not merely to show what it was, but to enable us clearly to determine what, if anything, there was in the training of his time that promoted, or even allowed, the development of so preeminent a genius. If the subject were properly studied and presented, much light might be thrown upon the problems of to-day.

One of the greatest of engineers, Leonardo invented the wheelbarrow and drained the Valley of the Po. He was an architect and a builder of fortifications. He was a great sculptor, and it seems doubtful if any other painter who ever lived could have left to the world both the Last Supper, in Milan, and Mona Lica, now in the Louvre. Moreover, he was a literary man and an investigator and inventor of high rank.

If he were alone in his day, it would be easy to account for him as a genius, a *lusus naturæ* like Shakespeare, so far beyond the ordinary great man that no systematic education could have really helped or hurt. But there were many others of his time, both men and women, whose attainments were broad and varied to a degree almost as marked. Michael Angelo, for instance, is immortal as architect, engineer, sculptor, painter and poet.

It surely can not be contended that school education has been essential to the development of great men or great periods in the world's history.

We have had in this country many examples of men educated to a high degree, who had none of the advantages of systematic training. No one can read the works of Benjamin Franklin without being impressed with the extent of his education and the completeness with which it fitted him to do great things. He, however, had practically no school facilities. Can anyone doubt that Lincoln was highly educated, in the only sense which is of much moment? We all know contemporaries of our own who have received but little schooling but are soundly educated and even cultivated men.

I have called attention to the comparatively small part that systematic education has played in the development of great men and of great eras in the world and in the history and progress of our race, not at all for the purpose of minimizing the importance of such education—the suggestion would be folly; the future prosperity of the human race and of every individual largely depends upon the extent and character of our educational facilities. I only desire to emphasize what seems to me the necessity that every man should recognize; that exactly as the Babylonians, the Greeks, the Romans, the men of the Renaissance and Benjamin Franklin were educated to an admirable degree—so that they could be both "speakers of words" and "doers of deeds"—without systematic schooling; so each one of us has the opportunity and the duty of supplementing the education that he gets in school and university, by exactly the methods which have been so effective in times when systematic education, as we know it, was not available.

In the matter of education outside of school and university, much depends upon the individual and his point of view. It would be of great advantage to every man if he could understand from childhood how necessary it is for him to learn outside of his definite courses of instruction, and how important it is that he should make the effort necessary for this self-education. If he were from the beginning impressed with the idea that school and university are but episodes—of course of the greatest importance—in what is really a matter of a lifetime, this thought would surely shape his conduct and his attitude from the beginning. He would not only unconsciously and automatically receive instruction from the world, as do we all, but he would be on the lookout for such instruction. He would cultivate his powers of observation, and of judgment and reasoning from facts observed. He would interest himself in more of the fields of human thought and human aspiration. He would seek acquaintance with more subjects of general interest. He would analyze more carefully the character and action of the men with whom he came in contact. He would realize the importance of the constant study of his environment.

In all this effort he would find the greatest satisfaction. By it he would bring himself, to the extent of his ability and opportunity, into close touch with all forms of human aspiration and human activity, past and present, and thereby learn to understand men and the world to a greater degree than would be otherwise possible. He would be sure to be strengthened in the fundamental virtues of truth, loyalty, generosity, integrity, justice and charity. For no man whose touch with human life and human history is really sympathetic, can fail to recognize that these qualities are at the basis, not only of society, but of that personal adjustment to social conditions which is of such supreme importance to each individual. He would learn that nothing human should be otherwise than interesting to him. He would find pleasure in studying and observing every field of human effort.

Nor is there any reason why this idea, if it occurs with renewed force at the period of graduation from the university, should not be accepted as of vital importance and become fruitful. If I have made myself clear, I urge you who have had the advantage of an admirable training in the Schools of Applied Science of this university, to take the thought to heart, and determine whether you can not develop it for yourselves to such an extent as to add essentially to your value to the community and to your own satisfaction in your work and in your career.

While every man is in a position to utilize the educational opportunities of after life to the greatest extent possible to him, within the limits imposed by his character and capacity, it is the university graduate who should be best fitted to profit by such after education. If he has done his duty in the university, his powers of observation are so trained that it is easy and natural for him to seek for and to absorb knowledge and ideas. He has learned to reason and to judge with accuracy. He takes real pleasure in intellectual effort. His imagination has been cultivated, so that he is in a position to apprehend not only the things that are obvious, but the other elements of a situation that are incapable of physical observation but which must be recognized in their true relations in order that the perspective may be right. More than other men, he ought to have an instinct for the truth, and the power of reasoning from things seen to things not seen; from the facts of the present, to the opportunities of the future.

It is sometimes said that the graduates of the schools of applied science, the engineers, the architects and the chemists of the world, while as a class excelling in industry, zeal, honesty, loyalty and many other of the fundamental virtues, are lacking in breadth of view and the capacity for dealing with large questions in a large way; exactly as is said of the graduates of the academic colleges that they are wanting in accuracy, persistency and definiteness of purpose and of methods. In so far as this criticism on graduates of schools of applied science has any foundation, the basis of it lies, I think, largely in the character of the work upon which, for four or five years, their attention has been concentrated. It is arduous work, requiring such intense effort as to make it difficult to turn away from it to matters not directly germane. Outside lighter pursuits are neglected. It deals primarily with the difficult facts and laws of nature, and while every moment there is full opportunity for the exercise of the powers of the imagination, the students of applied science do not always recognize this fact, or if they do recognize it, they are oppressed, as it were, by the seriousness of their effort to master the solid knowledge and methods of working which they know to be of first importance.

Moreover, this absorbing professional training is pursued with the definite interest and enthusiasm which is sure to characterize the effort to fit one's self for the specific vocation to which one's life is to be largely devoted, and it is natural that other things should be neglected almost as a habit.

It is immaterial for our present purpose whether or not there is any foundation for this friendly criticism as to the effect of a university education in applied science, acquired according to the best methods of instruction known at the present time. If it involves a narrowing influence, even to a slight degree, all the more is it necessary that the graduate of the university school of applied science should recognize the importance of definite self-education throughout his subsequent career. He will not remain stationary. He is sure to develop in some ways and in some directions throughout his active life. It is for him to determine the character and lines of his development and, very largely, its extent. The sole responsibility is upon him, and he can, at the most, only be aided by a consideration of the views of others. He must think for himself. But some things are very clear and others may be advanced as suggestions.

First of all, the graduate who has the right ambition for real success must never allow his attention to be so distracted from his vocation, whatever it may be, as to interfere with the doing of the actual work which comes to him, in the best possible way and with constantly increasing efficiency as his knowledge and power are enlarged by experience. Here, he must be sound and thorough. No amount of versatility in other things can excuse slackness or want of loyalty to the work and to the men for whom and with whom the work is done. These propositions are fundamental; but it is quite consistent with the most absolute fidelity to professional work to cultivate a large and varied interest in things outside of that work.

In fact, there can be no doubt that the professional work will be better done if other interests are recognized and pursued sanely and intelligently. New and difficult problems may arise at any time. Every piece of work that an engineer or chemist is called upon to do after he has passed through the preliminary stages of his active career, is likely to involve elements or conditions that are new in his experience. He will not find them, in the exact form in which they are presented to him, in any of the books that he has studied. He will be much better able to deal with each case as it arises, if, in addition to his strictly professional knowledge and experience, his faculties have been further trained by investigation and effort in other directions, to alertness, activity and soundness of reasoning and of judgment.

A knowledge of how to deal with men, in the various relations in which he meets them, is of vital consequence to the success of an engineer. This is a subject in which no courses are given in the university; it must be mastered in the school of life. The importance of such knowledge is not always recognized by the graduate who is just starting into work. Many men have failed, and many more have been delayed in their advancement to positions of profit and responsibility by incapacity in this regard.

One of the first lessons that the graduate of the School of Applied Science has to learn is that of discipline, which, in modern industrial enterprises where everything is based upon organization, should be almost of a military character. He does not always realize that it is by learning to obey that one becomes qualified to command. He does not appreciate that methods of work and of organization are now standardized to an extraordinary degree, and that many things which seem to him, in his ignorance, unwise or defective, are really based upon the results of a vast experience and intelligent study, resulting in the necessary compromises best adapted to produce results. Strict obedience and an enthusiastic submission to established rules and to the lines of the organization are prime requisites, the importance of which can not be overstated. When the graduate of the school of applied science has really mastered this lesson, he has gone a long way toward understanding the environment in which his life's work is to be caried on, and to fit himself for advancement and responsibility. He can act effectively and advantageously neither as a subordinate nor as an officer in the industrial army, unless he understands men in general and the individual men above him, below him, and on the same plane with him, with whom he has to work. Practically no two of them are alike. While the better he knows them the more he will appreciate their good qualities, he will always have to be on the lookout for their faults or eccentricities, and with these he will have to deal outwardly and in his own mind with justice and discretion, and always with charity, Even if he thinks that he sees things to criticize in his superiors, he must not only know but feel, that loyalty to them and to the organization with which he is connected, is of fundamental importance. He must be ready and glad to make sacrifices on all matters, except those of principle; to work with the greatest harmony and efficiency side by side with those who are of equal rank. He must not merely give orders to his subordinates, but must learn that to get out of them the best that each can give, he should gain their respect and if possible, their esteem. In dealing with others outside of his organization, there is required the same capacity for adaptation, involving a recognition of the real character and motives, and an application of the same virtues of justice, discretion and charity.

Another thing that the wise man learns, and more often practices in after life than in the university, is the right kind of modesty and self distrust. This is a merit only when accompanied by firmness, self respect, definiteness of purpose, and strength and promptness of thought and action; but the value of these latter qualities is greatly increased if coupled with them there is always a sane hesitation as to the accuracy of one's thought and action, which results in an effort to get light and assistance from every source and to neglect no precaution before the conclusion is reached or the step taken which is irrevocable. If, as seems certain, education in all directions is helpful in fitting one to deal with men and affairs, a constant recognition of this fact during the whole course of a professional career will lead to a fruitful effort to take advantage of every incidental opportunity to enlarge such an education.

But in addition to what comes from observation and experience, is it not also clear that in understanding men and in acquiring the ability to work with them on right lines, the graduate of the university school of applied science, and all other men, will be substantially aided by as great an acquaintance as possible with the recorded experience of others; with the thought, aspirations and achievements of the human race as a whole? From the earliest times we find that man has shown the same combination of good and bad qualities that he shows to-day. He has been actuated by substantially the same motives; the problems of life have been largely the same; and while his standards, moral, material and intellectual, have varied from time to time, the same underlying principles of life and conduct that we recognize to-day have, to a large extent, always prevailed.

Moreover, there is no profession so narrow and self-contained that it is not influenced by the general tendencies of our time in all directions. No man who is really grappling with his work and striving to master it is doing his full duty unless he gives some thought to the moral, social, political, literary and æsthetic movements which are influencing and shaping the character and history of the times. These can not, as a rule, be understood and their true meaning and probable future determined, except in the light of the history which has lead up to them and from which they have evolved.

An intelligent and sympathetic acquaintance with what have been and are the thoughts and aspirations of the race, as well as an appreciation of how those thoughts and aspirations have been and are developed in action and in conduct, is obviously of the greatest possible assistance in understanding and dealing with men. A study of them is almost a necessary supplementary training for professional work.

If I am right in this view, it should be the definite aim of every graduate from a university, in continuing his education throughout his life, to devote such portion of his time, as he can consistently with his other duties, to the sympathetic study of human effort and endeavor, and of human thought in other times as well as his own, and in other fields than that in which he is working. No man who is active in the affairs of life has the time to go far with such study, but everyone can accomplish something in this direction if he recognizes that it is a desirable and profitable thing for him to do.

It does not seem to me to make much difference in which field of the many that are open, such work is done. Each man should find out and work in those that are most attractive to him. He may work in one field after another, or in several at the same time if it is more agreeable to him, without sacrificing the advantage which he seeks. This is not a case where the same thoroughness is required as in the main work of a man's life. He is here seeking not so much for accurate and complete knowledge, as to quicken his apprehension and stimulate his imagination by learning what we have thought, dreamed, said and done.

Whether it is history or philosophy or poetry or literature or sociology or pure science to which attention is given, the time devoted will be well spent. Some men, but not many, can spend their spare hours pleasantly or profitably in studying Kant and Plato; every man can enjoy and profit by Shakespeare and Keats. If one's taste does not lie in the direction of political history, he can get equal advantage from the study of industrial progress. If he finds that modern social or political discussions are unattractive, he may get his pleasure and profit from a consideration of the questions of education that are pressing upon us. If he finds music incomprehensible, let him try to become interested in architecture or painting. If he is repelled by Herbert Spencer, he may get full benefit from Lord Cromer's volumes on modern Egypt. If he is not interested in botany, he may find what he needs in folk-lore or archæology. If he does not care for the history of science, he may get great profit and satisfaction from pure literature and the study of its development. Every man should surely have some outside interest, and he is fortunate indeed if he is attracted by every field of human expression.

Such nonprofessional interests, properly pursued so as not to interfere with professional work, will not only promote general capacity and aid in sound moral and intellectual development, but, in many cases, will add to a man's efficiency in his own specialty. Can there be any doubt that an engineer who has studied the architecture of Egypt, Greece, Rome or of the Middle Ages will become more accomplished in his work? Is it not certain that the imagination of the chemist or the electrician will be quickened by the study of other arts than his own, and even of pure literature, so that he will find his capacity for investigation and original thought distinctly improved? Will not a designer of machinery be aided in his every-day work by a knowledge of the principles of the fine arts and of the exquisite forms in which those principles have been expressed by the great artists?

It is a fundamental proposition that all the arts and sciences are related, and that a study of one helps in the practice of another. Is it not equally true that every field of human thought and effort is related to every other, and that within the limits of fidelity to his own work, no man can fail to gain in efficiency with every increase in his familiarity with what other men have been and are doing and thinking?

Thus far I have spoken of self-education, chiefly as a matter of advantage to the graduate of a university school of applied science in building up his character and adding to his efficiency. But there is another side of the matter to be considered. Each man should earnestly seek for all the real pleasure he can get in the world, and nowhere can he find it to a greater degree than in the study, however superficial, of nature and its manifestations, and of human thought and action and what has followed from them. Mere work without recreation is killing to the body and spirit. Physical exercise and out-of-door sports are a source of enjoyment to many and are of advantage to all, but they are not congenial to all ages and all temperaments, and are not of themselves enough. With most of us the mind needs to be rested and restored by active work in other than its ordinary lines of effort, and most of us can easily find some or many subjects of surpassing intellectual interest upon which to spend part of our time.

If I am right in my belief that almost any study, outside of his work, adds to the efficiency of the professional man and helps him in his chosen career, he is quite justified in definitely seeking to make this outside effort a relaxation and a pastime, by selecting that which is of most interest to him. If he knows none such, let him try one after another until he finds what he wants. Having found it, he may have, for all his life, in prosperity and adversity, an unfailing resource. He will know where to go for rest and cheer and comfort. The more such resources one has, the better; for the life even of the happiest and most successful is sure to have its periods of disappointment and anxiety in which one needs intellectual relaxation, both as a sedative and as a stimulant.

It is not to be forgotten, that, by the slight effort necessary to overcome the preliminary difficulties arising out of unfamiliarity, almost any field of intellectual or imaginative expression becomes attractive. This is particularly true of music and the fine arts, which certainly should attract the systematically educated man of our day, as they have attracted all classes, even those who have had no schooling, in so many great periods of the world's history. Some fail to appreciate great music, and yet almost every one would get pleasure and exhilaration from it, if he would simply take the trouble to hear enough of it to enable his faculties to come into harmony with its form and expression. It is greatly to be deplored that anyone should fail to apprehend as a personal delight the beauty of the Parthenon and the great cathedrals, or the pictures of the great masters, the study of which is sure to be a refreshing pastime to a cultivated man if he once finds out how to approach that study with intelligence. The wonderful concerts that are given in such large numbers in all our great cities every year, afford full opportunity for the training in music. Museums and galleries are accessible to most of us. Our public libraries are filled with books on the fine arts, and nearly every man can well afford to have some such books of his own.

Art and material things have become too far separated in our thoughts, as well as in our practice of to-day. In substance they are closely united, and the time will surely come in the future when, as in many periods of the past, the community at large will sympathize keenly with artistic expression and value it as on an equal plane with structural excellence.

Rudyard Kipling has recently written a poem in his characteristic style on the eternal "strife" and "hate" and "feud" between Jubal, "the father of all such as handle the harp and organ," and Tubal Cain, the "instructor of every artificer in brass and iron." This is a strange doctrine for the man who wrote "McAndrew's Hymn," "The King," "The Ship That Found Herself" and "Engine 007," with the definite purpose of showing how our modern industrial life is permeated with artistic and idealistic concepts. His former doctrine may have been an exaggeration, but there is no truth whatever in his picture of an earth-long conflict between

Jubal and Tubal Cain. Brothers they were by birth, the offspring of human need and human aspiration. Brothers they will remain until the end of time. It may be that they and their children do not now, for a brief moment, have the close relation which is natural and even necessary; but the happiness of the whole race is intimately related to the permanence of the tie which binds them in cordial harmony as types of the artistic and material.

The question may well be asked: Is there time for this self-education after graduation from the university? The work of the vocation is strenuous, and must not under any circumstances be interfered with. It takes many hours out of the day. There must be time for sleep; for physical exercise; for amusement and for social relations. A professional man has to adjust his life to all these requirements.

It must not be forgotten, that part of his education, which I believe should be definitely and consciously continued throughout life, comes as an incident to each and all of the other activities. It merely involves intelligent observation and thought as one is busy with his other affairs. No special time is required for this form of continuous education.

For the more systematic study of the interesting phases of nature and of life, past and present, which I so strongly urge, some time is surely required, but not necessarily a large amount; much can be accomplished if a few hours a week are given to such subjects, and no one can doubt that some hours can easily be spared for them. We do not always realize how much time we waste, not merely in doing nothing, but in matters that are really neither pleasant nor profitable to us. We must all read the newspapers that we may keep in touch with the events and current discussions of the day; but have not some a definite newspaper habit which kills time that might be much better spent in other ways? Is there not more theatre going than a sane man can justify in view of the present condition of dramatic art? Is not much time wasted in the innumerable magazines and weekly publications that could be otherwise better and more pleasantly employed? Is it worth while to wade through much of the modern fiction, which is manufactured and read in such quantities that it almost seems as if most of us must be devoting our lives to its perusal? A proper amount of attention may well be given to all these devourers of time, if they are a source of satisfaction, but too much should not be sacrificed to them.

Social engagements, casual conversation, and ordinary current amusement are delightful and profitable. Every man should participate in them, in his own interest and to promote and enlarge those friendly relations upon which so much of the joy of life depends. But devotion even to those may be carried to an extreme, so as to weary and disturb rather than to refresh and invigorate. While they should never be neglected, it is not at all impossible that sometimes one's feeling of social duty to himself and to others carries him beyond the point of mutual satisfaction, resulting in a real waste of time that might otherwise be better employed.

Almost all of us spend hours in the steam and street cars. Many of us have found here a large opportunity for reading and for study. We have learned to carry with us as a part of our regular traveling equipment, if the journey is to be a long one, not one book but several, each dealing with a different subject, that we may to some extent gratify the particular mood in which we happen to find ourselves. We can not carry a library in the street cars, but what would otherwise be a disagreeable morning and evening trip may be transformed into a pleasant excursion, if we take advantage of the opportunity to read one of the great English magazines, or a book of real value in which we are interested. Much more may be accomplished within the limits of the opportunities open to us than is generally realized.

If I am right in believing that a man's work is better done, and that he becomes a more useful citizen and gets far more satisfaction out of life if he makes a definite effort to take full advantage of the delightful educational opportunities which are within his own control; it is certainly well worth while for every man, and particularly every graduate of a university, to consider what he may accomplish in this direction, with the view of enlarging his horizon, increasing his capacity for work and pleasure, developing his moral and intellectual faculties and, in general, fitting himself to play a larger and more creditable part in the affairs of life.

FORESTRY AND HYDRO ELECTRIC DEVELOPMENT*

By H. L. Smith

Are we improvident? Are we, the American people, short sighted and profligate? Are we selling our birth-right, with little or no thought for the future?

The wonderful resources of the United States have been so often declaimed that, in our minds, they are reduced to the commonplace. If we stop to consider the subject at all, we are apt to regard these resources as our heritage and give little heed to the possibility of exhausting them, so vast do they now appear. Neither do we often reflect upon what the squandering of this inheritance will mean to us.

Not many generations ago our forefathers struggled heroically to clear small spaces here and there in the primeval forest, on which to build rude cabins and to provide the all too meagre subsistence for their families. Practically all of New England and the country from the Atlantic to the Mississippi was a gloomy woodland. Quoting from Roosevelt's "Winning of the West" we read: "It was not an open forest. The underbrush grew, dense and rank, between the boles of the tall trees, making a cover so thick that it was in many places impenetrable, so thick that it nowhere gave a chance for human eye to see even as far as a bow could carry. Here and there it was broken by a rare hillside glade or by a meadow in a stream valley; but elsewhere a man might travel for weeks as if in a perpetual twilight, never once able to see the sun, through the interlacing twigs that formed a dark canopy above his head."

Where may we now find even an approach to such conditions? You are doubtless thinking: How does this interest us, save as an indication of progress? and What bearing does this have upon the electrical or mechanical engineering professions?

Granite Creek Burn, Showing Effects of Fire One Year after Burn. Priest River National Forest, Idaho

Increasing Demands for Energy

Keeping pace with the marvelous industrial development of this country, the demands for sources of energy to supply the power for our great manufacturing plants are taxing our resources to their limit. The present vast and wasteful consumption of fuel is depleting the supply at an extraordinary and alarming rate. Despite the efforts of the skillful designer and the marked improvements in so-called high efficiency steam engines, turbines, fuel economizers, etc., only 15 or 20 per cent. of the total energy of the fuel is utilized. Somewhat higher efficiencies are shown in the recently developed gas engines; and it is even claimed that these engines, using producer gas, are destined to supersede steam engines and boilers on land and sea. With the advent of the gas producer, many fuels which in the past have been considered too poor for use in economic power development, are now giving, in many cases, an efficiency even greater than that produced by some of the best steaming coals.

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* Paper read before the Pittsfield Section A.I.E.E.

Alcohol, also, which can be obtained from a great number of waste vegetable products, may be counted upon to relieve the fuel situation somewhat.

Uses of Lumber

Let us consider for a moment the demands upon our forest resources and the effects of the exhaustion or diminution of our lumber supply.

Burned Stump Land, Carlton, Minn.

It requires one cubic foot of timber for each ton of anthracite mined.

In mining alone, 400,000,000 cubic feet of timber are used yearly.

Our railroads use 120,000,000 hardwood ties, which number requires the denudation of one-half a million acres of forest. At fifty cents a tie, this makes an aggregate of $60,000,000 for this item alone.

There are about 33,000 lumber manufacturing plants in the country turning out over thirty-five billion feet board measure, with an estimated supply of 1,240 billion feet available.

In 1905 there were 2,482 furniture establishments, with a total capital of $153,000,000, requiring together, 580,000,000 feet of lumber, practically all of hardwood.

Beside this there are 5,143 manufacturers of vehicles using only the best of hardwoods, hickory and oak being chiefly employed, the supply of which is rapidly diminishing. For agricultural implements alone, over 212,000,000 feet of lumber is used.

Steel and concrete are being used for car and house building and for telephone and telegraph poles, but in spite of this fact, the demand for hardwood lumber for these purposes is increasing.

The total lumber cut is estimated at twenty-five billion feet. The largest estimate of standing hardwood is four hundred billion feet. This means that the hardwood supply will be exhausted in sixteen years. In the East, soft woods are running low at nearly the same rate, and we shall soon have to fall back upon the Pacific coast supply, which will suffice for many years. For hardwoods, however, we shall have to turn to foreign markets or go without.

Thus we see that from the lumber standpoint alone the subject of Forestry is of decided importance to each one of us.

Water Supply

We have digressed purposely to indicate the value of our forests to some of our national industries. Confronted, then, with a rapidly decreasing fuel supply, with a corresponding increase in the cost of power obtained from fuel, we now turn to another of our great natural resources—our water supply,—more important perhaps to the life and pursuits of the people than any other.

Not so many years ago, before the days of railroads, the water-power of our rivers and small streams was employed for turning the wheels of the many small mills scattered here and there throughout the country. With the railroads and the opening up of the coal fields, came a new order of things: Manufacturing centers grew up with larger plants having better facilities, and the smaller mills were abandoned, leaving picturesque but pathetic landmarks of former days. Many of these larger mills, it is true, utilized the water-powers of the more important rivers, the location depending upon the water-power facilities and on the character of the water.

Manufacturing sites, however, were chosen in most cases rather with a view to their railroad and shipping facilities, and dependence was placed upon coal and steam engines for motive power. With the advances made in the generation and transmission of power by electricity, there has been a remarkable increase in the utilization of water-power for the operation of manufacturing establishments, railroads, and lighting plants. Many new industries, especially in electro-chemical and metallurgical branches, have developed as a result of cheaper sources of electrical energy.

It is our first impulse to turn to Niagara with the enormous power developments being undertaken there on both the American and Canadian sides of the river. Here 229,000 h.p. have been developed, with plans for an increase to 500,000 h.p. But perhaps these developments are not of the greatest importance, though more familiar to most of us.

The U. S. Geological Survey shows a minimum of about 2,800,000 indicated horse-power in the Southern Appalachian region, based on calculations from data taken during a period of fifteen years. Probably 50 per cent. of this is available for economic development. At $20.00 per horse-power year, this would mean a return of $28,000,000 per year, or nearly 3 per cent. on an investment of a billion dollars.

New England rivers, rising chiefly in the White Mountains, have enormous water-power resources, which are estimated at one-fifth of the total water-power of the United States.

On the four great rivers—the Connecticut, the Merrimac, the Saco, and the Androscoggin,—fully 350,000 h.p. are now being used, and this might be increased to over 500,000 h.p. without detriment to the æsthetic values of these streams. This is equivalent to the prospective development at Niagara Falls.

Without attempting to discuss or describe the water-power possibilities of the Middle West and Pacific slopes, let us study for a moment the significance of some of these figures. In passing, however, we might call attention to the fact that there are three corporations in California that are developing, or contemplating developing, 70,000 h.p. each. In Colorado there are great hydro-electric projects, many of which are being developed in connection with irrigation schemes.

New England has ever been an industrial rather than an agricultural community, and has attained a place of the first rank in the production of high grade woolens and fine cottons. The South, on the other hand, has been an agricultural community; but conditions are changing, and we now find it not only the leading producer of cotton, rice and tobacco, but a strong competitor in industrial lines. This is, of course, especially true in the case of cotton manufacture, where the Southern mills have their raw material close at hand, which condition is an important factor in the production of the heavier coarser cloths. In the Northern mills, however, attention is being given almost exclusively to finer cotton goods. Here only is obtainable the skilled labor requisite for the spinning and weaving of the finest yarns. For some of this cloth, a pound of raw cotton is spun into a thread about sixty miles in length, and the cost of transporting the raw material ceases to be an important factor in the cost of manufacture.

J. H. McShane Timber Camp, Rockwood, Wyo., Showing Brush Piling, etc., Bighorn National Forest, Wyo.

The electric drive was first used in the Southern mills. Pioneer work at Anderson, Pelser and Columbia showed the possibilities and advantages of this form of drive as compared with mechanical drive. Many northern mills followed suit, among which were the Lancaster and Soule Butler. The superiority of the electric drive is notable in cotton mill work on account of the greater flexibility of application and the nearer approach to the uniformly constant speed which is so important, especially in the spinning of fine cotton yarns.

The application of the induction motor to individual machine drive in all kinds of manufacturing enterprises, is a noteworthy feature of modern industrial progress. No less important are the rapidly increasing uses of electricity in the household, especially in the field of heating and cooking devices. These devices are rapidly becoming necessities rather than luxuries. Cheap power is, of course, desirable, and sooner or later we shall have to turn to the fuller development of the water-power resources at our command.

Stream Flow—U. S. Geological Survey

Turning to the reports of the Geological Survey we read:

Burned Forest Land Reseeded from Trees Several Miles Away. Original Stand Red Fir and Red Cedar; Reproduction Red, Noble and Amabalis Fir. Mt. Rainier National Forest, Washington

"The intelligent establishment and maintenance of enterprises or industries that depend on the use of water demands a thorough knowledge of the flow of the streams and an understanding of the conditions affecting that flow. This knowledge should be based on data showing both the total flow and the distribution of the flow throughout the year, in order that normal fluctuations may be provided for. As the flow of a stream is variable from year to year, estimates of future flow can be made only from a study of observations covering several years. The rapid increase in the development of the water resources of the United States has caused a great demand by engineers for information in regard to the flow of streams, as it is now generally realized that the failure of many large power, irrigation and other projects has been due to the fact that the plans were made, without sufficient trustworthy information in respect to the water supply.

"Owing to the broad scope of these hydrographic investigations and the length of time they should cover in order that the records may be of greatest value, it is in general impossible for private individuals to collect the necessary data, and as many of the streams traverse more than one State, this work does not properly fall within the province of the State authorities. The United States Geological Survey has, therefore, by means of specific appropriations by Congress, for several years systematically made records of stream flow, with the view of ultimately determining all the important features governing the flow of the principal streams of the country. In carrying out this plan stations are established on the streams and maintained for a period long enough to show their regimen or general behavior.

"During 1906 the regimen of flow was studied at about 700 stations distributed along the various rivers throughout the United States. In addition to these records, data in regard to precipitation, evaporation, water-power, and river profiles were obtained in many sections of the country."

U. S. Geological Survey Report

By referring to the tables in these reports, very accurate data can be obtained on the rainfall and "run-off" of most of our larger rivers and their important tributaries.

In computing the energy available for power development, the fall is generally taken as one-quarter of the total fall of the river. This gives fairly accurate results. Another method is to divide the length of the stream into three equal portions and take as the mean head available for power development the sum of one-sixth the fall in the upper third, plus three-sixths of the fall in the middle third, plus five-sixths the fall in the lower third.

This method, taking into account definite sections of the stream and the relative fall in each, is proven by test to be very nearly accurate.

Using the mean drainage area in computing the "run-off" per square mile, together with the mean head determined, the indicated available horse-power can be closely calculated. A formula for approximate computation of the horse-power of any water fall is: $\frac{\text{second feet} \times \text{fall in feet}}{11}$ = net horse-power on water-wheel at 80 per cent. efficiency.

Second feet = cubic feet per second = 40 California Miner's inches.

The following figures from the report on the Susquehanna River give some indication of the relation between precipitation and "run-off."

	Minimum	Maximum	Mean
Rainfall	51.6″	44.3″	39.4″
Run-off	16.6″	29.1″	21.6″
	49%	71%	54%

This shows that under normal conditions, about 50 per cent. of the rainfall does not increase the stream flow, but is held back by the earth, or is lost in evaporation, transpiration of the trees when in leaf, and by subterranean drainage.

Regulation of Flow

As the amount of power that can be developed profitably depends upon the length of the low-water season and the height and severity of the floods, it is important to study the conditions tending to regulate the stream flow or "run-off."

The rainfall is variable, and in order that the "run-off" may be approximately constant, the excess must be retained by the forests, ponds and lakes, or by artificial reservoirs.

Actual figures on the effect of the forests upon the flow of streams are naturally difficult to obtain, but that the forests do exert a potent influence on stream flow cannot be disputed. The reasons for this beneficial regulation are many; the leaves and branches of the trees break the fall of the raindrops; the roots keep the ground open and porous, assisting percolation; the humus and debris form a covering which prevents the sun from scorching and hardening the surface of the ground, thus checking the formation of rivulets and gullies and allowing the rain to soak in and be retained by the damp humus and earth beneath.

This forest cover—trees, dead leaves, underbrush, grass, weeds and decaying vegetation—is of the greatest value, acting as it does like a huge sponge. It absorbs and stores the water of the rainfall and snow, and retards the run-off, causing a much more even flow during the season. This result is naturally desirable, whether the water is used for irrigation or for power development, or both.

In the arid Western states the Government and private corporations are expending vast sums of money in irrigation systems, and the careful conservation of the water supply is of the utmost importance. Vast reservoirs are being constructed to store the spring floods and hold them until most needed in the dry season following.

The forests in the mountains also retard the floods, but in a different way, and furthermore serve another purpose of quite as much importance. The forest cover, as we have seen, checks the erosion of the soil by the rains and the washing down of silt. Where the mountain slopes are bare and the soil unprotected, the surface becomes baked and dry, and the waters quickly wash out gullies and carry great quantities of silt into the streams, covering the fertile valley meadows and filling the reservoirs, or forming bars and shallows in the navigable streams beyond. The prevention and disposal of this silt is one of the greatest problems confronting the engineers engaged in the construction of power and irrigation storage reservoirs. The McMillan dam in New Mexico was silted up 60 per cent. of its capacity within the brief period of eleven years—a serious matter indeed.

Hillside Erosion in Abandoned Fields, Catawba Co., N. C.

Again, by spreading a protecting cover of humus over the mineral soil and checking the velocity of the gales, the forest prevents the transportation of soil by the wind.

Still another effect of the forest, bearing more directly upon stream flow, is its probable influence upon precipitation. It is reasonable to infer that the relatively greater humidity of the air and the cooler atmosphere of the forests tend, at least, to increase the precipitation of rain.

Forests occur only where there is a mean annual precipitation of 18 or 20 inches, but they border streams for long distances into the plains where the precipitation is less. In sections where the mean annual precipitation is below 18 inches, we find shrubs and herbage in place of larger trees. The mesquite, which grows on the arid plains in Arizona and Mexico, is dependent on the seepage waters from adjacent mountains, and its roots often delve 20 or 30 feet below the surface.

Forest Preservation

Is not this subject quite as important to us as the currency problem which is attracting universal attention just now? The American is said to be indifferent, so long as you do not affect his purse, but it is evident that our own pocket-books are actually in danger. Are we not spending our capital instead of conserving it? Are we not exceeding the speed limit and rushing towards the brink of the precipice with brakes off and both hands on the throttle? Fortunately for us, some remedial measures have already been taken to avert the impending disaster. At present these measures can only defer the time, but they are of sufficient importance to warrant our careful consideration.

Silt Bar in Navigable Stream, which has Developed into an Island. Dredges at Work Removing It

Most of us have at least heard of the National Forests, but some have no definite understanding of their true purpose and use.

In 1891 Congress authorized President Harrison to establish the first forest reserve—the Yellowstone Park. Much opposition was offered, and this was often justified at first, as mistakes were made both in the selection and handling of the lands set aside. In most cases the reserves were simply locked up, with no provision to utilize the resources or protect the timber from the ravages of fire.

In 1897 this condition was remedied by a law making it possible to use all the resources and to provide proper protection. More careful surveys have been made and agricultural lands put back into the public domain and excluded from new forests or additions. Very accurate reports are made by trained men, stating the importance of the proposed reserve in the regulation of water flow as well as its value in supplying timber. The effect upon local industries and the establishment of homes is carefully considered.

National Forests

There are now 153 national forests, with about 145,000,000 acres in the United States and about 5,000,000 more in Alaska and Porto Rico, distributed as follows:—Arizona, 9,000,000 acres; California, 21,000,000; Colorado, 15,000,000; Idaho, 20,000,000; Montana, 20,000,000; Nevada, 1,000,000; New Mexico, 7,000,000; Oregon, 16,000,000; So. Dakota, 1,000,000; Utah, 7,000,000; Washington, 12,000,000; Wyoming 9,000,000; Alaska, 4,000,000; beside Kansas, Nebraska, Oklahoma and Porto Rico, which have less than 1,000,000 acres in each. Many others are proposed, chief among which are the White Mountain and Southern Appalachian forests, upon which we have to rely largely for the preservation of our hardwoods.

Taken altogether, these National Forests have already been productive of great good. Instead of locking up the land and its resources, they rather unlock them, but cautiously keep the key. They not only make the vast mountain ranges more valuable, but by wise regulation keep them so.

As the National Government pays no taxes, these lands are of course withdrawn from taxation. By a provision of the Forestry Act, 10 per cent. of the receipts from the forests is returned to the counties in which these lands are located, and this provides a constant and ever increasing source of revenue, with which the probable utter loss of these values to the county, if the forests were sold to be logged and afterwards left in barren desolation, is not to be compared.

Congress has extended the Homestead law, slightly modified, to the National Forests; so that the homeseeker can patent any of the small agricultural lands, which are of necessity included in the reserve, and make his home there subject to the laws. Such settlers are encouraged, as thereby more men are available to assist the guards in fighting fires. So effective has this fire patrol become that but one-third of 1 per cent. of the total area of the National Forests has been burned since their control.

The settler is allowed as much timber as he requires for domestic purposes free of charge. The prospector or miner is free to explore the forest as much as he likes, and to stake his claim and develop any mineral resources he may find. He, too, is allowed free use of the timber for his mining work. The National Forest does not affect his work in any manner, except that it keeps timber in the country for his use and so helps him to succeed.

Grazing, if not prejudicial to the good of the reserve, is permitted throughout the National Forests under Government jurisdiction. The settler with small interests has the use of the ranges to which he has the best right, and may not be crowded out by larger interests. At present over 1,500,000 cattle and horses and 6,000,000 sheep are grazing upon these lands. Overcrowding, overgrazing, and disputes between owners are prevented by proper supervision.

Hillside Erosion in Abandoned Fields, Catawba Co., N. C.

In 1906, 75,000,000 feet of timber was given away and 700,000,000 board feet sold. Of the latter, nine-tenths was in amounts netting less than $500, which indicates that the small man is not being shoved aside by the big timber corporations.

Water Rights

The National Forest does not have any effect upon the utilization of the water supply. The forest conserves the supply and makes its development profitable. The appropriation of water rights is governed entirely by the state or territorial laws. Railroads, trails, flumes, canals, reservoirs, power-houses, and transmission lines may be constructed wherever needed as long as they do not inflict unnecessary damage to the forest. Improvements of this nature are encouraged, as they tend to open up the country and to increase its growth and prosperity.

Forest Utilization

It will be noted that the use of the timber in the National Forests, while restricted, is not prohibited. With proper care and under skillful direction, this may be made a constant source of revenue, giving highly satisfactory returns on the investments.

Many states now have a state forester whose duty it is to educate the people in the care and planting of trees; to investigate the causes of fires and secure suitable wardens; and to stimulate active interest in the betterment of forest conditions.

In this study we have much to learn from France and Germany, where forestry has become an exact science.

In France there are over 23,000,000 acres of forest, covering about 18 per cent. of the total land surface. These forests are to a large extent subject to Government supervision, and return an annual yield of approximately $2.50 per acre.

On the same basis our 145,000,000 acres of National Forest would produce a yearly income of over $360,000,000, a very tidy asset.

In this country, we find the recent bill before Congress for the Appalachian Forest Reserve appropriation, meeting with indifferent success. This is right at our doors, and it is upon the Appalachian and White Mountain ranges that we are dependent for headwater control of our important Eastern rivers from which we must seek, sooner or later, the fullest development of their water powers.

The American Institute of Electrical Engineers, as well as many other engineering bodies, realizing the vast importance of these matters, are adopting resolutions to give active support to all worthy measures that are seeking to conserve the forests, to protect what we already have and to plan for the future. Let us then acquaint ourselves with the facts and, from selfish motives, if you please, lend our support to these measures and all others which will strengthen the arm of American forestry, which is destined to have the greatest effect upon the future prosperity of this country.

ELECTRIC AUTOMOBILES

By Alex. Churchward

Recognizing that the electric automobile is becoming an accepted adjunct to the transportation of merchandise in our large cities today, it may be well to give a brief history of its development up to the present time.

Nearly all of the earlier vehicles of the larger size were driven by motors mounted on the rear axle, the method of transmission being usually of the single reduction spur gear type. In the smaller sizes, such as runabouts, live rear axles with differentials and single motors were used; while in the larger sizes two motors and dead rear axles were employed.

The method of control adopted in these earlier types was what is known as the commutated battery system, the controller changing the connections of various sets of cells from parallel to series, thereby varying the speed of the vehicle by varying the impressed e. m. f. on the motor. The main disadvantage of this method of control was the unequal discharge of the different battery sets when connected in multiple. The mileage of these earlier vehicles was quite low compared with the results obtained today from the same size battery, the reason being that the friction, or in other words the wattage, was excessively high.

It has been shown that motors mounted directly on the rear axle are necessarily of low speed, are comparatively heavy, and their efficiency on overloads not high; and further that the transmission under average conditions is not very efficient. A great deal of experimenting and investigation made by a prominent electric automobile builder along this line during the past few years, has shown that to obtain the maximum vehicle efficiency, the weight below the springs must be reduced as much as possible.

Next in order came the double reduction motor, mounted on or suspended from the body of the vehicle, the power being transmitted from the countershaft (or in some cases where slow speed, single reduction motors were used, from the motor shaft), to the rear wheels by means of chains and sprockets. The vehicle efficiency of this type of transmission was found to be higher than the direct spur geared type, due to the increased flexibility in the driving mechanism, less weight on driving axle, better distribution of total weight, and the use of a lighter, higher speed, and more efficient motor.

In 1903 one company placed on the market a new and lighter type of commercial vehicle, the principal features of which were:

Net weight, approximately 0.6 of that of any vehicle of similar carrying capacity;

Flexible armoured wood frame;

Single motor, with roller chain drive from motor to countershaft;

Double chain drive from countershaft to rear wheels.

Although this vehicle, in the smaller sizes, was capable of carrying nearly its own weight, it was found to be efficient and satisfactory in service. This was due to the great flexibility of the running gear and transmission. Such was the success of this type of vehicle that it proved conclusively that the weight could be reduced considerably in all types of electric vehicles, without impairing the efficiency or increasing the cost of maintenance.

Following along these lines, nearly all the standard vehicles today, with the exception of some few makes of the heaviest trucks, are equipped with a single motor and double chain reduction, although great improvements have been made by different manufacturers on this single motor type of vehicle.

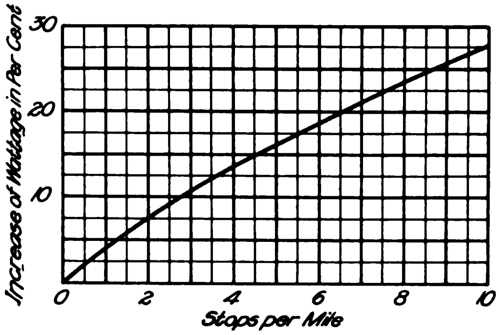
The first reduction roller chain has been replaced by a silent chain, the efficiency of this chain at high speeds being much greater than that of the roller chain. The plain bearings in the wheels are being replaced by some type of roller or ball bearings. Pressed steel frames are used for the smaller size vehicles, while steel channel frames are employed for the larger sizes; these frames being so designed as to retain the necessary flexibility and strength without increasing the weight.

Great strides have been made in the design of motors especially suited to this single motor construction, the efficiency having been increased on normal and overloads many per cent., while all unnecessary weight has been removed, without impairing the steep torque charactertistics so essential to motors taking their energy from storage batteries. The net result is that the vehicle efficiency has been considerably increased.

The design of the controlling apparatus has also been modified to suit this new condition. The standard practice today is not to commutate the battery, but to combine the field windings of the motors with proper shunting, and thus obtain a greater number of speeds at higher efficiency than formerly.

On all the older types of vehicles, the controller used opened the circuit between controller points, the result being arcing and burning of contacts, and expensive wear and tear on gearing, motor and tires.

In 1904 the General Electric Company brought out a new controller which obviated all of these troubles and increased the mileage and the life of tires and batteries. This controller is so designed that the motor circuit is not opened at any point from the first to the last, the torque on motor never falling below a certain predetermined value. It is known as the "continuous torque controller" and is applicable to both single and double motor equipments.



Percentage Increase of Wattage Due to Stops

Much study has been given by vehicle manufacturers to the reduction of the friction or wattage of their vehicles. A few years ago a commercial vehicle consuming 120 watt hours per ton mile on hard level asphalt was considered successful, but lately this limit has been reduced below 100 watt hours per ton mile, and in some cases, under favorable conditions, as low as 60 watt hours per ton mile has been obtained.

Although the wattage of a vehicle on hard level asphalt cannot be taken as a criterion of what the vehicle will do in actual commercial service, yet it serves as a basis upon which all calculations of mileage and traction can be made. The number of stops per mile has a great influence on the wattage of a vehicle, and as the mileage of any vehicle, with a given battery, is approximately proportional to the wattage, the number of stops to be made will therefore directly affect the possible mileage. The percentage increase of wattage due to stops is shown in the accompanying curve. The wattage is also influenced by the type of tire used. With solid tires of different makes the free running wattage may vary from 10 to 15% on hard level asphalt, but the difference becomes less apparent on grades or rough roads. How necessary it is to reduce the wattage per ton mile of all vehicles that derive their energy from storage batteries, is shown in the accompanying table.

even a greater variation with different makes of pneumatics than with solid tires. A vehicle equipped with a single tube cord tire will have a radius of nearly double that obtainable when equipped with a standard double tube tire. Several of the tire companies have designed a special fast low-wattage tire, of double tube construction, for use on electric carriages, but although the radius of action is nearly that of the single tube cord tire, the liability to puncture is just as great.

Battery Type	WATT HOURS PER MILE									
MV	50	60	70	80	90	100	110	120	130	150
7	35	29	25	22	20	17.5	16	14.6	13.5	11.7
9	47	39	33	29	26	34	21.5	19.5	18.	15.7
11	58	49	42	36	32	29	26.3	24.2	22.3	19.3
13	71	59	50	44	39	35	32	29.5	27.	23.5
15	82	68	58	51	45	41	37	34.	31.5	27
17	94	79	67	59	52	47	42.5	39.	36.	31.5
19	105	89	76	66	59	53	48	44	40	35
21	122	102	88	76	68	61	55	51	47	41

It will be seen from the above that if a vehicle takes 120 watt hours per ton mile with a 21 MV, the maximum ton miles per hour are 51; while if the wattage is decreased to 60 watt hours per ton mile, the mileage is doubled or a much smaller battery (11 or 13 MV) can be used for the same distance to be covered. Thus, by reducing the friction or wattage of a vehicle, a smaller battery can be used, as well as a smaller motor, and the whole vehicle weight can be reduced.

Below is given a table showing the effect of different pavements and conditions on a 1000 lb. delivery wagon of standard design.

On pleasure vehicles, some form of pneumatic tire is nearly always used, and there is

There has therefore been the choice between long mileage (per charge) with the liability to puncture and its attendant dangers, and short mileage with the comparative safety of a stronger tire. Lately, a non-puncturable inner tube has been brought out, and has been thoroughly tested. If this is used in conjunction with a special low wattage outer casing, we then arrive at the possibility of long mileage (per charge of battery) with comparative safety and a low tire maintenance.

From tests lately made, the combination of this inner tube and a fast outer casing does not increase the wattage perceptibly over that of the same casing with an ordinary inner tube.

	Max. Miles Per Charge	Watt Hours Per Ton Mile	Vehicle Speed Miles per Hour (Max.)
Level asphalt	57	80	10.5
Lavel macadam	47.5	95	10
Level asphalt 5 stops per miles	49	93	10.5
Level macadam 5 stops per miles	41	110	10
Level asphalt 10 stops per mile	44	103	10.5
Level macadam 10 stops per mile	37.5	122	10
Asphalt 1% grade	41.5	110	10.2
Macadam 1% grade	38	120	9.9
N. Y. City average 5 stops per mile	41.6	109	10.2

PATENTS*

PART II.

By ALBERT G. DAVIS

The ordinary process of enforcing a patent is by suit for infringement in the federal courts. As I have said, a patent is granted by the United States Government, and it is enforced in the federal courts, and is enforced by suit. The only way to protect yourself, if you own a patent, is to sue for infringement, either before a jury (which is seldom done in this country), or in equity before a judge. These suits are long, expensive and troublesome. There is not a lawyer practicing to-day who would not be glad to see a means of shortening and making them more simple. Nobody seems to be able to find out how to do it unless we adopt the English system of trying patent cases in open court before a judge, which is a system in some respects superior to ours.

A man files in court a Bill in Equity, in which he sets forth: that he owns this patent, that it was properly granted, that defendant infringes it, and other things; and prays the court to compel this defendant to come into court and show why he is doing this wrong. The Court issues a subpoena—which is a summons—and the defendant comes into court by his lawyer and says the patent is bad—sets up any defense he pleases—and thereupon the parties take testimony; that is, have witnesses come before a Notary Public in a lawyer's office. The lawyer comes into the office, the witness is produced, the Notary Public or examiner swears him. Day after day they sit examining the witnesses, with a stenographer to take down the testimony, until they have what they call a record; that is, until they have said all they want to say, a process which frequently consumes several years and costs a great deal of money. This record is printed, and is brought into court and argued before a judge. Now in equity, if the judge finds a patent to be valid, he may grant a written injunction commanding the defendant to stop doing this thing, and that written injunction is practically the vital thing in a patent suit. The court may also award damages, or may award the profits which the patentee would have made if he had not been prevented by the defendant.

There is another power in the Court, which is the so-called Preliminary Injunction, or Temporary Restraining Order. This injunction is the one so much talked of in labor difficulties now-a-days. The theory is this: If a man had some right which was being assailed by an irresponsible person, or if some irreparable damage was threatened, the Court might issue a preliminary injunction to keep things in their original condition until the right could be definitely ascertained. Take, for instance the case where a man owned an estate merely for life (a circumstance which was common in England), and someone else was alive who was entitled to that estate at his death; and the tenant for life on this estate committed waste—cut down the ancestral shade trees, or dug mines in places where it was against the rule to dig mines—doing something to impair the the value of the property, the Court would issue an injunction to prevent him from doing it. Or assume the case where a man is wrongfully in possession and the owner is suing for the property, and the person in control proceeds to commit waste. He knows that he will be thrown out eventually, and thinks he will get what he can out of it and turn it into money. If this happens, the Courts issue writs of temporary injunction, preventing this from being done, and maintaining the *status quo* until the case is settled. Our temporary injunction in patent suits is based on this. We say we have a good, strong, valid patent, and that we have invested money in this business; and here comes an irresponsible person who is competing with us, lowering our prices, selling an inferior article and spoiling our reputation, and so on. On that basis, we sue him. I have already said it may take a year or two to get a suit settled; so we petition the court for a temporary injunction, preventing him from further depredations and maintaining the *status quo*. These are sometimes granted, but ordinarily, only when the patent has been sustained in another suit.

To obtain a patent an application is prepared, containing a petition, specification, drawings and claims, and an oath. The petition is respectfully addressed to the Commissioner of Patents. The inventor makes the statement that he is sole and true inventor, etc. These papers, together with fifteen dollars, are deposited in the Patent Office and given a number—called the Serial Number, which is the application number, not the patent number—and are referred to an Examining Division. There are some forty odd examining divisions, some having to do with the electrical arts, some with the various mechanical arts, etc. Each of these divisions has a Chief and five or six assistants called Assistant Examiners. These are mostly young men, college graduates. They read the application through very carefully, see if it conforms with the law, if the drawing shows the invention properly, etc. And then they look at the claims, study each claim by itself separately, and see if every combination claimed in that case is new. Ordinarily they do not find them all to be new. They then write a letter to the applicant or his attorney, criticizing the drawing, perhaps, and stating that the applicant forgot to sign his name; that the ink is pale; that such and such a word is spelled wrongly in the specification; that the description is not full and complete so that they can understand it, etc.; that claim one is rejected on such and such a patent, such and such a publication, and so on. The attorney reads this letter, gets out his references, and tries to see wherein the invention is not described fully or is anticipated. He often finds that he made his claim too broad. He writes a letter back to the Patent Office in which he may modify or erase some claims, and may respectfully set forth his reasons for insisting that some of these claims are not met. And so goes the correspondence between the attorney and the Patent Office, which correspondence sometimes extends over a period of several years. The law only requires an attorney to answer a letter from the Patent Office within one year after it is written, but he must answer the letter fully and advance the case each time. Finally, the Examiner will have reduced the claims to a point which he considers proper, and the case goes out of the Examining Division, and the inventor receives notice of allowance. He is given six months in which to pay the final fee of $20.00, and the patent is then issued.

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* For first part of this article see May issue.

It does not always go as smoothly as that. Sometimes the attorney and Examiner disagree, and in that case there is a system of appeals which can be carried to certain courts in the District of Columbia; but the ordinary applications go through as I have said. You will see the importance of having a good lawyer to draw the application, a man who knows something about the art and invention. I do not know of any other branch of the law which requires the ability that is needed to draw a really good patent application. It is an exceedingly difficult document to draw, and requires a man who is a great deal of a lawyer, a great deal of an inventor, and a prophet—for he must look ahead. Usually the inventor does not know what he has invented; he has not put it in its proper place in the art. The inventor ordinarily sees only one side of it, and it is the unusual thing for a case to be properly drawn. You might go to the very best patent lawyer in this country with an invention, and, I say, it would be the unusual thing to find out years afterward, when the patent was subjected to the test of courts, that it had been really well drawn—you will generally see where it could have been drawn better.

It occasionally happens that two, three, or four men invent the same thing at about the same time, and my chief in the Patent Office, years ago, would jocosely advance the theory that there were "invention microbes" going around biting people to make them invent things, and if the same microbe bit two different people they invented the same thing! Some such theory almost seems necessary to account for the enormous number of cases where the same thing is invented by different people at about the same time. When two or more applications are pending in the Patent Office simultaneously, claiming or trying to claim the same invention, the office institutes Interference Proceedings to find out which is the first inventor. A certain official in the Patent Office, called the Examiner of Interferences, decides which of these is entitled to the invention, and from his decision an appeal may be had to other tribunals, and the proceeding is long and expensive.

In such a proceeding, the first question is as to who first reduced the invention to practice; that is, who first put the thing in practical form. It is not merely, or mainly, who filed the application first (although the filing of the application is regarded as equivalent to putting the invention in practical form), but the question is, who first reduced the thing to practice. Broadly speaking, he is the inventor, unless the other party to the interference can show that he was the first to see it in his mind in practical form,—to have a definite conception of the invention—and that he was using due diligence at the time the other party was making the invention. This means that if you make an invention, put it on paper, get witnesses, and do nothing else; and if somebody else subsequently makes the invention and files his application before you file your application, or builds the machine and runs it before you file your application, he is the first inventor. He is the inventor unless you show that at the time he came into the field, you were using reasonable diligence in perfecting that invention. In other words, you cannot sleep on your invention. In our practical experience it has happened that a man would come in with a sketch which he had had several years, asking us to get a patent and telling us that some other company was putting it out, although he was the inventor. He had made the sketch and filed it away. It would, obviously, be an injustice if we could, with that old piece of paper, take the invention away from the man who gave it to the world.

I have heard a man say that the average inventor is too secretive. His idea was that if a man makes an invention he should tell everybody about it—put it in the newspapers. That advice is not always good, but the Courts have ruled that no man can prove his invention simply by his own testimony. Even after a patent is issued, a man can take away that patent from a patentee, or rather get a new patent for himself, by showing that he is a prior inventor and that he was using reasonable diligence; unless he is barred by Sec. 4886, RS, as by two years' public use, etc. Usually then, a patent can be taken away on a proper showing that the patent was not issued to the really first inventor; therefore, it is necessary that a man should have his proofs in proper form. In the documents intended as proof of invention, the thing should be fully described. We want a man to write a good, specific letter, and have it witnessed by two or three witnesses—we want our proofs. We can then follow the thing up and put it through. The secretive inventor who is afraid to tell of his invention is always taking the chance of someone else, some independent inventor more communicative than he, taking his invention away from him.

Many employers require that inventions made by employees along the employer's line of work shall belong to the employer. This rule is enforced by contract in many cases. With the General Electric Company it is a rule, whether a contract exists or not. This policy has been criticised by inexperienced men and by men unaccustomed to inventions; but as a rule, it has not been criticised by men who have made important inventions; such men have recognized that it is necessary, and eminently fair and proper.

In my experience it is rare for an invention to spring complete from one mind. It is ordinarily worked up through a long and painful process involving considerable expenditure of time and money. Of course one man, or one set of men, will take the last step, will devise the actual thing which goes into use, will make the suggestion which finally makes the device operative and successful. This man or group of men will necessarily have to make the patent application, but much of the real credit may well belong to others.

I do not suppose any question would be raised if we made a practice of keeping our various processes of manufacture secret, as an employer is ordinarily supposed to have the right to do; and I presume that an inventor, who under these circumstances devised a secret process and saw it put into use under his instructions in our works, would consider himself bound to keep the secret when he left us. Now, in a concern as large as the General Electric Company, it has been found practically impossible to keep secrets, and it is, in general, the policy of the Company to try to obtain through the patent law that protection which it cannot obtain by secrets. The only way in which this can be done is, of course, to have the inventor execute a patent application and assign it to the Company.

It should also be remembered that patents are not granted for every form of original work; in fact they protect only a limited range of inventive skill and effort. The man who lays out a great power transmission, carefully choosing the number of phases and voltages, arrangements of apparatus and circuits with reference to peculiar conditions; the man who designs a great generating station to meet the circumstances existing in some particular city or railway; the man who devises a scheme of financing, or who conceives a new idea in connection with the sale of our apparatus; all these men use their minds and use them in a highly creditable way, and sometimes the amount of ability and even genius required for such work is almost infinitely greater than that required to make the ordinary mechanical invention. None of these efforts are capable of protection by the patent system, so that the employee gets from them no benefit except the recognition of his skill and diligence, which the Company ought to give him, and which the Company tries to give every employee who does good work in its behalf. Why should the man whose mind happens to run in the direction of that limited class of original work capable of protection by the patent laws be treated in any different way?

And so it is the policy of the Company to enforce the rule which we have mentioned above, and to endeavor as far as it can, to recognize good work in any form, inventive or non-inventive; the good work of the mechanic, foreman, superintendent or manager; the good work of the draftsman who lays out designs in such a way that the machine will properly fulfill the function for which it was intended, who puts enough material here and not too much material there; the good work of the commercial man; the good work of the clerk; the good work of every man who, in his sphere of action, does something for the benefit of the Company. That particular class of effort which leads to patents on inventions is somewhat more tangible, somewhat more easily recognized than any other class, and for that reason my experience shows me that it has been in general recognized, if anything, in more than its proportion to its deserts.

In closing this branch of the talk I can only say to those few who criticise or object to our system, that I would like to have them sit down and work out a policy on which they would run an organization of the size and complexity of the General Electric Company, which should be based on any other principle; to consider whether they would dare to assemble together thousands of good men from all over the world and to lead them into the very inside secrets of the business of the Company; to put them in a position where they are capable of making little improvements or big improvements; to put them in touch with the vital problems of the art years before the average inventor ever hears of such problems, without enforcing some such practice.

Now I suppose in considering any question, any system, any institution, it is worth while to stop and see if it is a good thing. No system is perfect, and no system is free from disadvantages, one of which in the Patent system may be the amount of money that it has cost. There have been taken out in this country about 800,000 patents. If we assume that these cost $100.00 apiece, we get $80,000,000 for the cost of taking out these patents. If we assume $1,000 apiece to cover time of the inventor, experiments, etc., the sum becomes enormous. Another objection to the patent system is that it can be used as a vehicle of oppression. I suppose there is no power which cannot be used for evil. It has been said, and said doubtless with some measure of truth, that some great corporations sometimes oppress small corporations by filing patent suits against them without good cause, and this has been done—there is no question about that. I do not think, however, that it is a common practice. Where this is done once, a corporation is oppressed, pestered and harassed a hundred times by the dishonest claims of fake inventors. However, the patent system has built up the interests of this country. No man, no corporation, nothing except the government could afford to run our research laboratory unless the patent system existed to protect the result of the work. The history of the steam turbine is a history of pouring hundreds of thousands of dollars into its development, and now the patent system of the United States is the thing on which we depend to help us to get our money back. The world at large is richer for the gift of this new prime mover, and the people who had the courage to put their money into it will find that the patent system will make it easier to get their money back. I think the same principle can be applied to all industries in which great sums of money have been spent, relying on the patent system for returns. Inventors, men of courage, perhaps men of poverty, sacrifice, work and struggle along year after year, and at last bring out an invention; and the patent system has given them their encouragement and brought them their reward. And such a system as that is one which should be criticised in the spirit of benevolence, rather than in the spirit of destruction.

ELECTRIFICATION OF THE HARLAN AND HOLLINGSWORTH PLANT

By H. B. Emerson

Power and Mining Engineering Department, General Electric Company

The Harlan & Hollingsworth Corporation of Wilmington, Del., are builders of vessels up to 4000 tons burden; also of railway, passenger, dining and parlor coaches.

Their plant, situated in the southwestern part of the city of Wilmington on the banks of the Christiana River, covers about thirty-five acres of ground and consists of the following buildings, arranged as shown in Fig. 1: Power station, machine shop, pattern shop, millwright shop, brass foundry, boiler shop, blacksmith shop, tin shop, punch shop, mold loft, ship-joiner shop, four car shops, a truck shop, mill and office building.

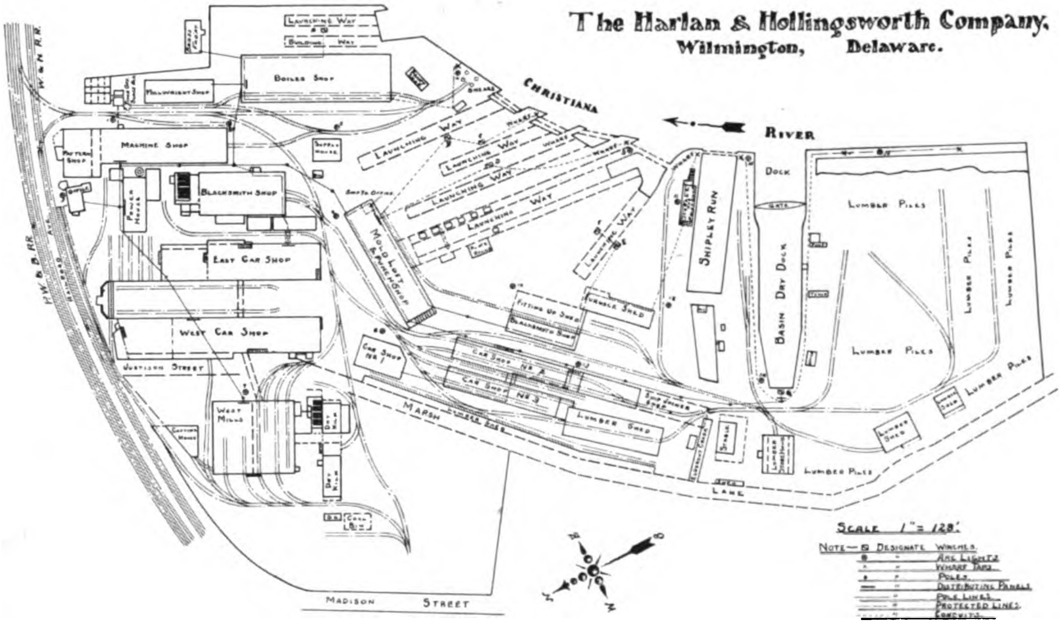


Fig. 1. Ground Plan of Plant

There are also seven launching ways, a dry dock, and a number of small buildings.

Originally the machinery in this plant was driven by long lines of shafting and several steam units located at various points about the plant, but finding that their transmission losses were very high, the company decided in the early part of 1906, to remodel their plant to some extent, and to change to the electric drive.

They therefore erected a central power station and installed two General Electric 300 kw. 150 r.p.m., direct current, direct connected generators; one General Electric 150 kw. Curtis turbo-generator; one 50 kw., direct connected generator; and a nine panel switchboard (Fig. 2) of blue Vermont marble, with the necessary instruments, switches and protective devices for controlling and protecting the generators and the various feeder circuits to the different buildings for purposes of lighting and power.

All of the generators are of the 3-wire compensated neutral type, wound for a normal potential of 250 volts, and capable of delivering 125 volts between the neutral and either main. This type of generator was installed in order that the Edison 3-wire system of distribution could be used with 115 volt arc and incandescant lamps for the lighting system, and 250 volts employed for the constant and variable speed motors on the power circuits.

Figure 3 shows an interior view of the power station, which is of modern cement construction and contains the condensing apparatus, an air compressor for operating the various pneumatic tools, (such as riveters, chisels, etc., about the plant), and a fire pump.

They also erected a new boiler shop, 120 ft. wide by 300 ft. long, of steel construction and modern in every respect; transformed their old boiler shop into a blacksmith shop, and built a new ship-joiner shop. The boiler shop and ship-joiner shop are equipped almost entirely with new machinery, and while some group drives exist in the joiner shop, almost all of the machinery in the boiler shop is individually driven.

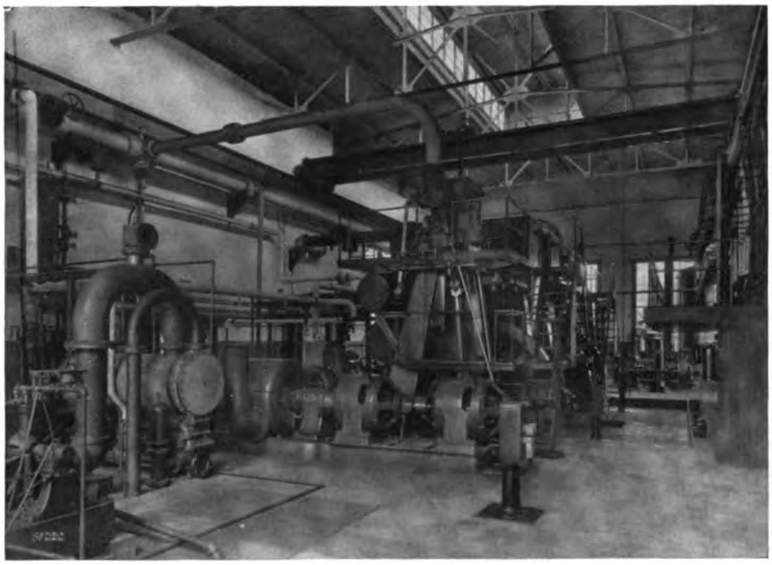


Fig. 3. General View of Power Station, 150 Kw. Turbine Set in Foreground

The company uses the two 300 kw. generators for their average day load, keeping the turbine as reserve power, and for night work when needed. The 50 kw. generator is also used at night and on holidays (when only a few machines are running and few lights needed), or for lighting the yard and dry dock when it is necessary to dock a boat at night and no other machinery is in operation.

The feeder circuits from the power station to the various buildings are carried on a pole line, as it was not feasible to use underground conduit, owing to the land being only a few feet above tide water.

Each building is provided with a black enameled slate distribution panel where its feeder terminates; from this all branch feeders in that building can be controlled or cut off if necessary.

Lighting

The yard lighting, dry dock lighting, and general illumination in the shops is taken care of by the use of 115 volt, 5 ampere, enclosed,

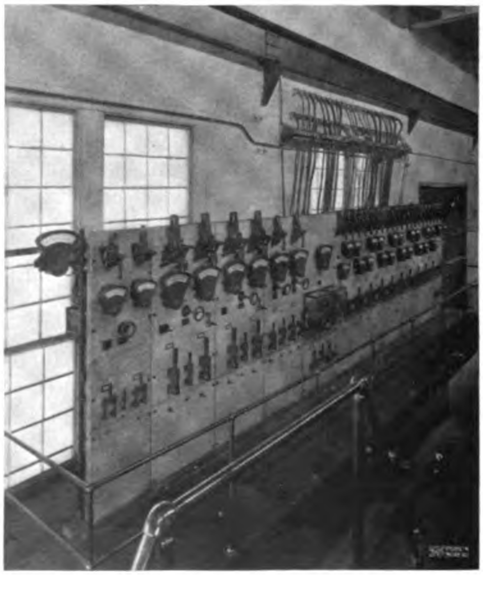


Fig. 2. Switchboard in Power Station

long burning General Electric arc lamps, while the office and individual illumination is accomplished by the use of General Electric incandescent lamps of various types, meridian and tungsten lamps being used in the office and drafting room, and the ordinary carbon filament, 16 candle-power lamps in the shops.

Power

The various machinery throughout the plant is driven either grouped or individually by 230 volt, direct current motors. Individual drives are used on isolated tools and those of large capacity where the work is handled by overhead traveling cranes, as well as on tools requiring minute variation in speed and those frequently used for overtime work. Group drives are employed on the smaller machinery where little or no speed variation is required; on automatic machines; on machinery the operations of which are relative, and on old machinery not worth the expense of individually driving.

As above mentioned, the boiler shop machinery is nearly all driven individually, and here may be found some of the largest and most modern machinery of its kind in the world, most of it having been built specially for this plant.

The shell-drill shown in Fig. 4 is truly a modern machine. It is equipped with nine motors, three for each head—one for raising and lowering the rail, one for driving the tool, and one for moving around the track. Three operators are employed on this drill, one for each tool, and each can work entirely independently of the others.

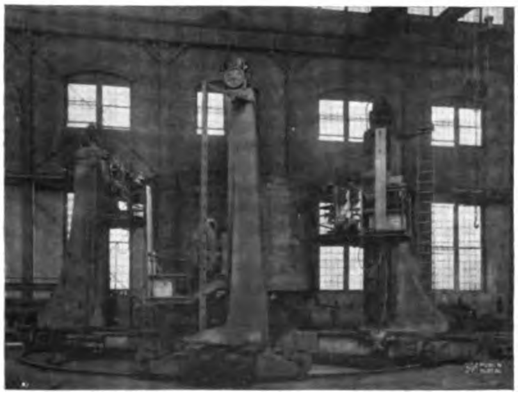


Fig. 4. Bethlehem Steel Company's Shell Drilling Machine

The 25 in. and 20 in. by 12 ft. vertical rolls (Fig. 5) are worthy of note. Here two motors are employed, one of 75 h.p. capacity for driving the rolls, and the other of 50 h.p. capacity for changing the draft. Beside these there are horizontal bending rolls, a plate-edge planer, oval hole cutter, tube drill, punches, shears, gang drills, bolt machinery, and the miscellaneous machinery which goes towards making an up-to-date boiler shop equipment.

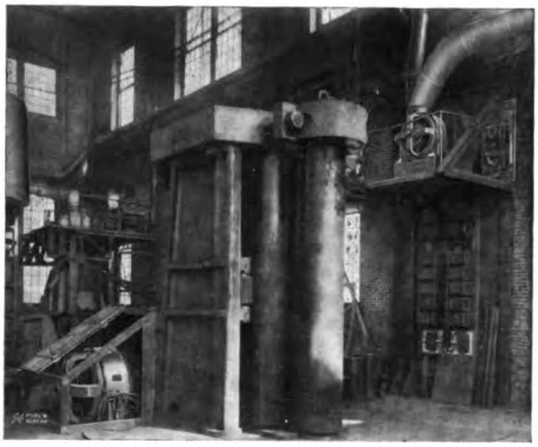


Fig. 5. Bethlehem Steel Company's Vertical 25 and 20 in. x 12 ft. Rolls

This shop is thoroughly equipped with overhead electric traveling cranes, so that the work can be easily handled and brought to, or carried from, the various machines with a minimum amount of manual labor.

The machine shops are equipped with some new machinery, the most interesting being a large double-head lathe which is used for turning up the large propeller shafts. Each head is equipped with a 38 h.p. motor, and the lathe is so arranged that two operators can work on it without in any way interfering with each other. Another machine of interest in this shop is the universal boring, milling and drilling machine (Fig. 6). This is also equipped with two motors, one for changing the position of the head along the base rail, and the other for operating the tools or changing their position vertically. All motions are controllable from the operator's platform. Figs. 7 and 8 show a shear and a milling machine, also driven by individual motors, and by inspecting the cuts it may be seen how the motors have been adapted to the tools, and not the tools to the motors.

There are seventy-six motors in the plant, of which number fifty-three are constant speed machines, and the rest variable speed. Most of the individual drives use variable speed motors of the General Electric CL and CR types, controlled by General Electric drum type controllers placed within easy reach of the operators. In each case all of the various motions on the machines are controlled electrically, as it was the object of the installation to place the operator in a position to obtain the maximum amount of work from his tools in a minimum space of time.

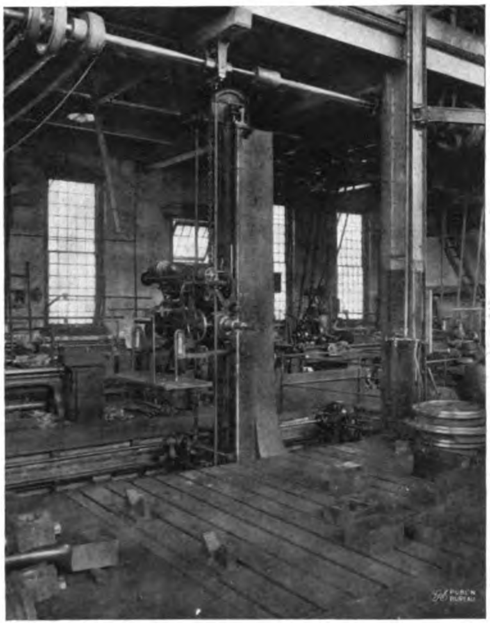


Fig. 6. Thomas Shanks & Co. Universal Boring, Milling and Drilling Machine

The ship-joiner shop is thoroughly equipped with up-to-date wood-working machinery. The large machines, and those likely to be operated only a part of the time, are individually driven; while those in more or less constant duty, and doing work which is relative (that is, where a piece of work is started in one machine and finished in another), are grouped. This shop is also equipped with a modern shaving exhauster system, the fans being motor-driven. All shavings from the various machines are sucked up through pipes to the fans and then blown to the waste bins in the boiler house, 500 feet away.

The machinery in the smaller buildings is mostly driven in groups, although isolated machines are driven individually.

The mill, situated at the northwest corner of the plant, has not up to the present time been changed.

In the yard around the launching ways and dry dock are a number of electric winches, used for hoisting material about the ways, for pulling boats in and out of the dry dock, and, in fact, for any purpose where a warp or whip hoist may be used.

The 75-ton shear legs (Fig. 9), situated at the eastern dock, are electrically equipped. Here a series motor is used with a drum controller and solenoid brake, the solenoid brake being mounted directly on the armature shaft, and always set except when current is on the motor. With this outfit, a completed boiler, spar, or other heavy piece of apparatus may be transferred from the dock to a vessel with the utmost ease.

The 75-foot transfer table, for transferring cars from one shop to another, or from the shop to the delivery track, is also electrically equipped, as is the 70-foot turn-table in front of the roundhouse; in fact electricity has been used wherever power is necessary, and the total motor capacity in the plant aggregates 1326 h.p., showing a load factor at the power station of approximately sixty per cent.

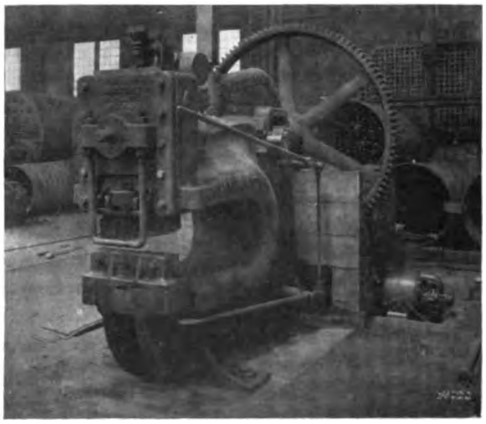


Fig. 7. Hilles & Jones No. 6 Shear

On the second page of this issue is shown the dry dock, where general boat repairing is executed, and as the work often has to be done at night, or when a boat desires to dock on a night flood tide, it is necessary to have very good illumination. Around the dock, therefore, are placed fourteen General Electric, 5 ampere, enclosed arc lamps, and several dock tap terminal boxes from which leads for incandescent lamps or portable arc lamps can be run. Power for small tools, such as portable drills, decker planers, etc., can also be taken from these same dock terminal boxes.

The electrification of this plant has shown a great saving over the old method of drive, and can, perhaps, be best appreciated by reading the following letter received from Mr. W. G. Coxe, president of the corporation:

"It has occurred to me that it would be of interest to know that the electrification of our Plant, the entire installation of which was carried out by your Company, has been in operation a little more than a year, and I feel sure you will be glad to know that up to the present time the repairs to the entire installation have not exceeded $20.00, all of which is very satisfying to ourselves and certainly speaks well for your products. The economies which we have secured have more than realized our expectations, for previous to the electrification of our plant the daily consumption of coal averaged about thirty-five tons; this, of course, being considerably exceeded in the winter months owing to the fact that several of the Corliss engines were located between 600 and 700 feet away from the boiler plant. Our present consumption runs from sixteen tons as a minimum to twenty tons a day as a maximum, the consumption depending of course on the variation of the load and other conditions.

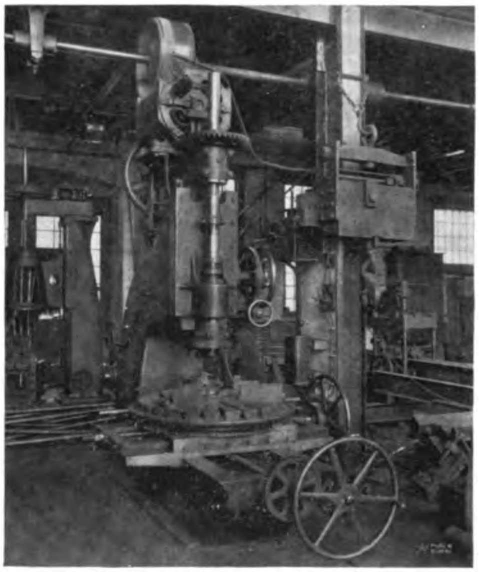


Fig. 8. Bennet Mills Vertical Milling Machine

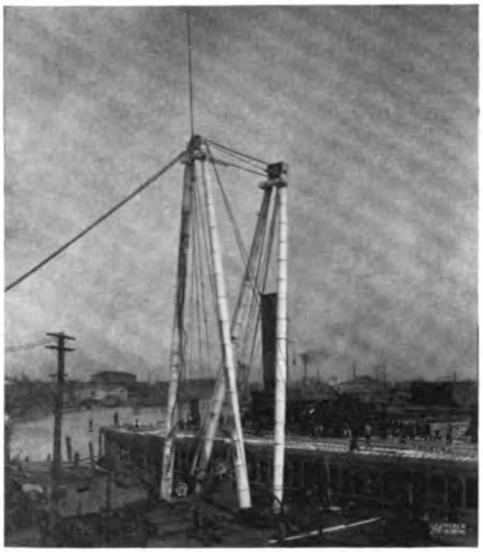


Fig. 9. Shear Legs

With the above results you can readily understand that we congratulate ourselves on having placed the electrification of our plant in your hands and feel that you can be congratulated on securing the results that we have so far obtained."

In conclusion, it might be stated that the above showing, it is believed, can be considerably bettered when the west mill is thoroughly modernized, which improvement the company expects to accomplish in the near future. This building was not changed during the process of regeneration, as wood-burning boilers are situated at the south end of the mill, where all of the shavings from the ship-joiner shop and the mill itself are burned, and it was supposed that there would be enough waste to furnish steam to the engine driving the mill. It is found, however, that a considerable amount of coal has also to be used, and it is now thought best to use as much of this waste as is necessary for heating the dry kiln; to electrify the mill and cut out the greater part of the present shafting and belting. When this is done, the load factor for the whole plant will undoubtedly be somewhat higher, and the economy considerably greater than that obtained with the present drive.

THE FLAME CARBON ARC LAMP

By S. H. Blake

In spite of the short life and high cost of impregnated carbons, the intense brilliancy and remarkable efficiency of the flame carbon arc are making it more and more popular in this country. Regarded at first as only suited for advertising purposes, it is now rapidly finding a more premanent field of usefulness. Although it seems quite impossible that it will ever be used here for general illumination to the extent that it is now being utilized abroad, the flame carbon arc must be considered a prominent factor among the various new illuminants.

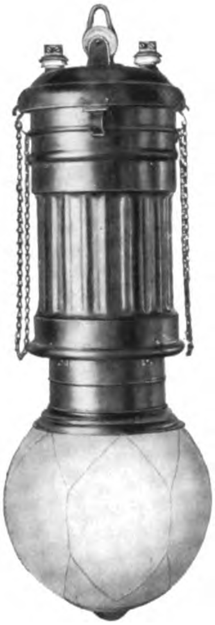


Fig. 1. G.I. Flame Arc Lamp

Practically all the light from the ordinary carbon arc comes from the hot tips of the carbons, the arc itself, formed of carbon vapor, giving off only a very faint bluish light. The high efficiency of the flame carbon arc results from feeding into an ordinary carbon arc certain mineral salts which, when vaporized and raised to the temperature of boiling carbon, make the arc itself intensely luminous, and of greater length and thickness than that produced by pure carbon. In order to effect this result cored carbons are used in flame carbon arc lamps, having either the core or tubular shell of the carbon, or both, impregnated with light giving mineral salts.

The color of the light can be varied over a wide range, being dependent upon the characteristic spectrum of the impregnating salts. Three different colors of flame carbons are standard on the market; namely, yellow, red and white. The light producing efficiency varies considerably, however, for different salts, those giving yellow light being much more efficient than any of the others. Fig. 2, shows the distribution in the vertical plane and the relative efficiencies of the lights produced with flame carbons giving different colors.

Arc lamps using impregnated carbons have been very highly perfected in Europe, particularly in Germany, and up to the present time practically all of the flame carbon lamps sold in this country have been of foreign make or design. These foreign lamps are complicated in construction, as compared with the various makes of enclosed lamps now in common use in this country, and the purpose of this article is to describe a flame carbon arc lamp that is just being placed on the market by the General Electric Company that is believed to be better suited to American requirements than the foreign types.

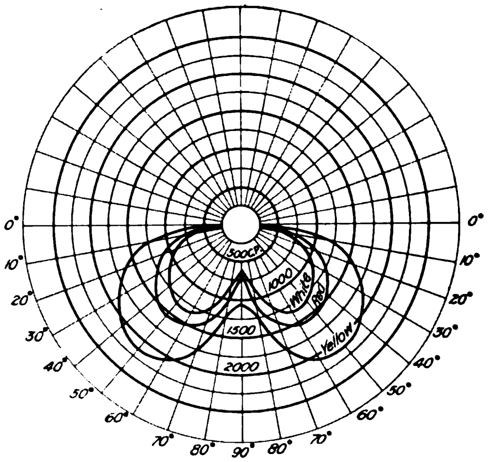


Fig. 2. Distribution of Light in a Vertical Plane; Yellow, Red and White Flame Carbons

The external appearance of this lamp is shown in Fig. 1, the casing being drawn seamless from either sheet copper or steel. The standard finish for the copper casing is "antique," and for the steel, "bright japan." The mechanism of a direct current lamp is shown in Fig. 3, and that of the alternating current lamp is identical in appearance except for the fact that the two small resistance spools shown in the upper part of the lamp are omitted. This lamp has no chain feed or complicated escapement and clock mechanism. It is of the inclined carbon type, with nothing below the arc to obstruct the light. Both carbons feed by gravity simultaneously, while the regulation of the arc is accomplished by the lateral movement of one carbon with relation to the other. When the casing is lowered into the trimming position every part of the lamp becomes accessible.

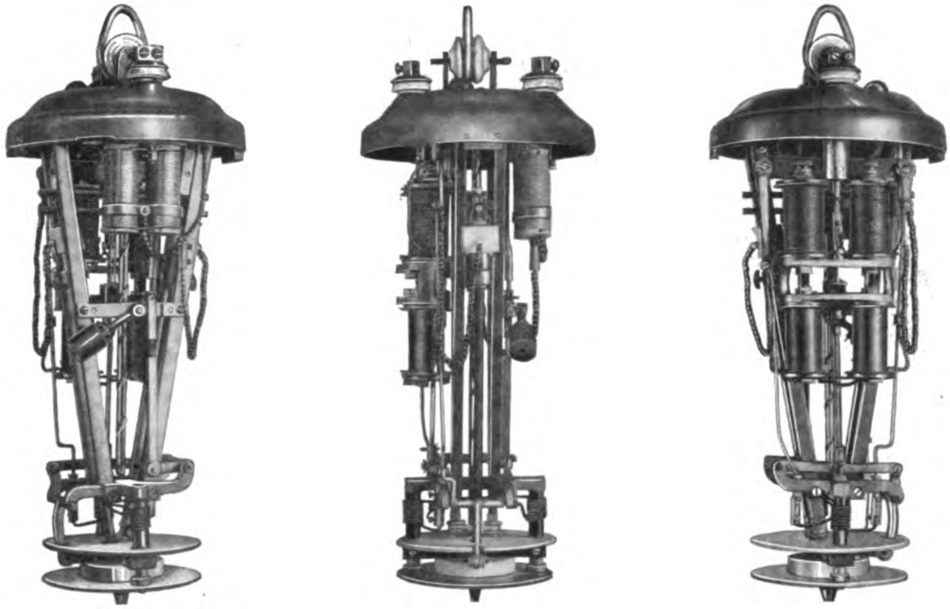


Fig. 3. Interior Views of G-I Flame Arc Lamp

A serviceable "economizer" of refractory material surrounds the points of the carbons just above the arc, so as to prevent the "washing" of the carbon ends, and to steady the arc from the effect of air currents as far as possible. A "blow magnet" is so situated with relation to the arc that it performs the double function of keeping the arc steadily fan-shaped at the carbon tips, and of totally extinguishing it if for any reason it encroaches dangerously near to the economizer. The economizer, therefore, is well protected from burn out, and should last indefinitely. A heavy baffle plate of insulating material is placed just above the economizer, effectually preventing any appreciable amount of the products of the arc from depositing on the parts of the mechanism. During operation the lower surface of the bottom plate of the lamp and that of the economizer become coated with white deposit from the arc, which deposit acts as an excellent reflector for the upward light from the arc.

All lamps are equipped with light opal globes. They are designed to burn two in series or singly, across 100 to 125 volts direct or alternating constant potential circuits, and can be used on any frequency from 40 to 140 cycles. The lamps may be wound for either 8, 10 or 12 amperes, the last mentioned current being considered standard.

They will burn indoors about twelve hours per trim, and not less than ten hours out of doors, the alternating current lamp taking two carbons 400 mm. by 10 mm., and the direct current one carbon 400 mm. by 10 mm., and one carbon 400 mm. by 9 mm.

The illumination curve of Fig. 2, shows the distribution of light in the vertical plane of the alternating current lamp at 12 amperes, 60 cycles, when trimmed with yellow carbons and operating with and without light opal globe.

PRESENTATION OF THE PERKIN MEDAL

By Dr. C. F. Chandler

It is my privilege as the senior Past President of the Society of Chemical Industry residing in this country to make the actual presentation of the Perkin Medal to our distinguished brother chemist, John B. F. Herreshoff. It seems hardly necessary when speaking to an audience of chemists, to enter into any details with regard to Mr. Herreshoff's great achievements in the field of industrial chemistry, but in order to make a record for this occasion, I will take a few moments of your time to give you a brief sketch of some of Mr. Herreshoff's more important labors.

The improvements and inventions of Mr. Herreshoff began in 1875 and have continued down to the present time—a period of over thirty years. From 1875–1890 he was associated with the firm of G. H. Nichols & Company; from 1890–1900 with the Nichols Chemical Company; and from 1900 to the present time with the Nichols Copper Company and the General Chemical Co.

During these thirty years of active industrial development, Mr. Herreshoff has applied his mind to a very great variety of chemical and metallurgical industries, and has perfected many most radical improvements that have assisted greatly in reducing the cost of production and improving the quality of the products manufactured by these companies.

He has substituted scientific management for the old fashioned rule of thumb in the conduct of all the operations which have come under his direction, and has thus developed the highest standard of factory control.

Copper Smelting

At an early date Mr. Herreshoff devoted his attention to copper smelting and invented the well-known smelting furnace for this metal which has long borne his name, and which was patented in 1883. Prior to this date brick furnaces had been almost exclusively used, and the separation of the matte gave very crude and unsatisfactory results. His furnace is steel enclosed and water-jacketed, with a movable fore-hearth or well, placed on wheels and so designed that the slag or the matte running out of the breast of the smelter must pass directly into the hole in the side of the well, placed 8 or 10 ins. below the molten mass that overflows from the opposite side of the well. In this manner the air blast is suitably trapped, and coke is prevented from running into the well. The matte, after accumulating in the well, is tapped out from time to time.

The success of this furnace became generally known, and the steel water-jacketed furnace with a movable well is now almost universally employed, except where reverberatory furnaces for special reasons offer economical inducements.

A number of these furnaces have been used in Canada in the Sudbury district for smelting nickel and copper ores. They are also used in the Ducktown district in Tennessee, and in Mexico, and have been used for a long time at Laurel Hill.

The Chamber Process for Sulphuric Acid

Mr. Herreshoff directed his attention at an early day to the improvement of the chamber process for manufacturing sulphuric acid, and succeeded in developing the most advanced process that the world has ever seen—at least up to a short time since. In accomplishing this result his ingenuity was taxed in innumerable ways to provide the necessary apparatus with which to put his advanced ideas into practice.

The atomizers devised by him for the injection of weak sulphuric acid into the chambers were a great improvement, and at once reduced the steam consumption one-third.

He succeeded in reducing the consumption of nitre to 1 per cent., on the sulphur burned.

He then devised the Herreshoff tower, which is a modification of the Glover tower, and is designed for denitration and for concentration. In place of the brick or self-sustaining walls of the Glover tower, finely crushed material (preferably quartz) is used, and the lateral pressure due to the interior filling or filter bed of the tower, is resisted by suitable iron plates outside of the lead sides of the tower. This lining of fine material is thus held suitably in place, and is prevented from passing or washing into the filter portion of the tower by an intermediate layer of quartz, crushed to sizes from ¼ to ½ in. The filter bed is sustained by cross bearers of quartz. The bottom is so constructed that it completely resists the action of very hot acid of very high strength.

The great advantage of this tower is that its life is exceedingly long, being nearly indestructible. In operation the heat of the burner gas is retained by having a nonconductor over the arch, and this high temperature assists greatly in giving perfect denitration, although the acid is concentrated up to 63° or 64° Be. The acid coming from this tower is so free from iron and alumina that it is run directly into a platinum still or pan, and concentration is completed in another pan constructed of iron, the hot gases from the furnace passing directly under steam boilers. This invention effected a very great saving, and has been in use from 1885 to the present time in the earlier works of the Nichols Company and in all those of the General Chemical Company.

Herreshoff then developed an extremely ingenious apparatus for concentrating the sulphuric acid delivered from the Herreshoff tower. The hot acid from the improved tower is first concentrated to 65° in platinum. It is then run into an iron pan for concentration to over 66°. From this pan it runs into a large cast iron pan and while passing through it most of it is distilled off and condensed in a platinum Liebig's condenser to 66°. This acid is free from arsenic and otherwise very pure. The acid which passes through the stills without distillation represents a small proportion of the total and has a strength of 98 per cent. The amount of fuel used in the distillation is very small on account of the small latent heat of sulphuric acid of this strength. This improvement in the distilling apparatus came as the result of the increasing demand for a purer sulphuric acid than could be obtained by the ordinary methods of concentration. Dr. Lunge, the great authority on sulphuric acid, in his master-work on this subject, states that the claims Mr. Herreshoff made for his still were impossible. Nevertheless, at one single establishment 100 tons of distilled sulphuric acid were produced daily from pyrites, that compared favorably with the concentrated acid made from brimstone, satisfying the demands at the time for purity, and at a price at which brimstone could not profitably compete.

His almost indestructible Glover tower made it possible to concentrate the acid to a much higher strength than had previously been attained, and this, in conjunction with the aforesaid stills, produced practical results that in the stage of development then existing were almost revolutionary.

Herreshoff's improvements in the Gay-Lussac towers were also very marked, enabling him to use enormous quantities of sulphuric acid in absorbing, while at the same time the elevation to which the acid had to be pumped was greatly reduced.

Roasting Furnaces for Pyrites Fines

His next invention was patented in 1896 and consists of an improvement on the original idea of the Gilchrist & Johnson type of Roasting Furnace; that is, a roasting furnace intended for roasting fine iron pyrites ores. Heretofore a great many roasters had been devised but none of them were satisfactory. Even the Gilchrist & Johnson furnace was a failure on account of the inability to make repairs without completely shutting down the furnace, the arms being bolted solidly to the central vertical shaft. This bad feature was overcome by an improvement that made it possible to take out an arm, the teeth of which were no longer serviceable, and replace it by a new one in one minute. A marked improvement in this furnace was made and patented by Herreshoff in 1899.

When this improved furnace was put on the market there were immense quantities of fine ore in various parts of the country that could not be sold on account of the inability to roast it, especially for sulphuric acid making, without great cost and trouble. This ore was used up very rapidly thereafter, rendering available, say, 3,600 tons a day of fines pyrites which hitherto had been a kind of drug in the market. When one estimates that this means the production of more than 1,500 tons of sulphuric acid a day, he can see the importance of this furnace to that industry. There must be over a million tons of fines ore roasted in these furnaces annually, or enough to make approximately two million tons of oil vitriol per annum. The enormous accumulation of fines ores thus became almost as valuable as lump ore. These furnaces have not only been adopted in a large way by chemical works and fertilizer factories, but also for desulphurizing ores in connection with copper refining. Up to this time there have been sold 478 furnaces in the United States and 644 in Europe, making a total of 1122 furnaces. Most of these are used for roasting pyrites fines ore in manufacturing sulphuric acid. They have a capacity for burning 3,000 lbs. of sulphur in 24 hours, and assuming that they are all used in the manufacture of sulphuric acid, the amount of acid produced as oil of vitriol is about 2,500,000 tons per year. They are still being sold quite extensively in Europe as well as in this country. They have been a great boon to the fertilizer industry of the United States, especially in the South, where most of the pyrites ore is in quite a fine condition when mined.

They have also made possible the use of pyrites, in place of brimstone, for the production of paper pulp, because by their use a sufficiently rich gas can be produced.

The Electrolytic Refining of Copper

The next great work which Mr. Herreshoff undertook was the development of the electrolytic refining of copper, which was at that time practised in a very small way in two different works in the United States. His plan for electrolytic refining was entirely different from anything that had been devised before, or, as I believe, since. The electrolytic refining of copper was not at that time well understood. Even the analytical work necessary was quite inaccurate. The improvements and development which resulted from Mr. Herreshoff's study of the problem were only made possible by the highest scientific attainments, and the aid of a corps of men thoroughly trained by him for the work. As a result, he has created in the past ten years the largest copper refinery in the world, which in itself is a clear indication of the fact that his processes have been eminently successful in the perfection of their results, as well as in their pecuniary economies. The output of this refinery at the present time is about 1,000,000 lbs. of copper per day, or about one-fourth of the world's entire output.

In connection with this work Mr. Herreshoff invented an apparatus for casting metal, used especially for the casting of the thin anodes employed in the series system for making electrolytic copper, which has brought about a large saving, and which is very extensively used.

The Contact Process for the Manufacture of Sulphuric Acid

Mr. Herreshoff's crowning achievement has been his work in developing the contact process for the manufacture of sulphuric acid.

Taking the magnificent work of Dr. Knietsch as a foundation, and the splendid engineering work of the Badische Company in Germany, Mr. Herreshoff, as the result of more than one thousand investigations, in which he was ably assisted by others, but which he directed, made that process not only adaptable to American conditions, which are quite different from those for which it was originally intended, but has also economized very much on the whole cost of the operation, so that now the contact system is an established process in this country. It has made possible the production of sulphuric acid of the highest strength, including anhydrous sulphuric acid, at a lower cost than by the old chamber system with the necessary concentrating plants in connection therewith, and now an acid virtually chemically pure can be supplied to the largest manufacturing industries in unlimited quantities at a lower price than previously known.

Conclusion

In addition to the great achievements which I have already mentioned, there are many others. Mr. Herreshoff has produced almost an evolution in every chemical manufacture which he has undertaken, increasing the yields, decreasing the cost, and improving the qualities of the products. One of the great secrets of Mr. Herreshoff's success is his ability to concentrate himself upon any given subject which he has in hand. It is impossible to make a catalogue of the achievements of a great man. Mr. Herreshoff is an engineer by birth and a chemist by education. He is a typical chemical engineer, unsurpassed in this calling. It is eminently proper that he should be selected by the representatives of the great chemical societies of this country to receive the Perkin Medal, which was founded a little more than a year ago in honor of the great chemist who laid the foundations of the great coal-tar industries, which have had in the past fifty years such a profound influence, not only upon the chemical industries of the world, but also upon abstract chemical science.

ROTARY CONVERTERS

PART VI*

BY ERNST J. BERG

Automatic Phase Control

By this is meant automatic control of the voltage by changing the phase relation of the alternating current. As previously shown (equation 10), the general equation for the voltage at the receiving end of the line is

$$e = -(ir + i_1x) + \sqrt{e_0^2 + 2\,ii_1rx - i^2x^2 - i_1^2r^2}$$

Let the no load electromotive force be e_n; then at no load $e = e_n$

The no load wattless current $i_1 = i_n$

At no load $i =$ zero.

Thus, $e_n = -i_nx + \sqrt{e_0^2 - i_n^2r^2}$ (12)

Let the full load e.m.f. be e_f; then at full load $e = e_f$

The full load wattless current $i_1 = i_f$

The full load energy current $i = C$

We then have:

$$e_f = -(Cr + i_fx) + \sqrt{e_0^2 + 2C\,i_f\,rx - C^2x^2 - i_f^2r^2}$$

(Equation 13)

Several assumptions may be made regarding the relation between wattless lagging currents at no load and wattless leading currents at full load; and, depending upon these assumptions, the relative strength of the shunt and series field vary. Two conditions will be considered; first, when the converter operates non-inductively at about one half load; second, when the converter operates at full load.

Assuming, in the first case, that the rotary will take as much lagging wattless current at no load as leading wattless current at full load, we get, $i_n = -i_f$.

Further, denoting $\frac{e_f}{e_n}$, the ratio of the full load rotary voltage to the no load voltage, by k, and solving equations (12) and (13) for i_f and i_n we get:—

$$i_f = -\frac{e_n^2\,(k^2-1) + 2\,ke_nCr + C^2z^2}{2e_nx\,(k+1)} \quad (14)$$

and

$$i_n = \frac{e_n^2\,(k^2-1) + 2k\,e_nCr + C^2z^2}{2\,e_nx\,(k+1)} \quad (15)$$

Let F_0 = the field magnetomotive force (obtained from the saturation curve) which gives the voltage e_n, and which corresponds to minimum input.

F = the shunt field magnetomotive force for voltage e_n under any condition of load.

T = the number of turns of the series field. (Assuming that all direct current goes through the series winding.)

C = the rated full load alternating current.

p = the ratio of the full load direct current to the alternating current;

thus $p = \frac{\text{direct current}}{\text{alternating current}}$.

As shown previously

$p = \sqrt{2}$ for single-phase rotary.
$= .943$ " three- " "
$= .707$ " four- " "
$= .472$ " six- " "

The magnetomotive force of the series field for any alternating energy current is $i\,p\,T$.

Let R be the full load armature reaction; then, as discussed above, 1.15 R is the equivalent armature reaction. The armature reaction corresponding to any wattless current i_1 is $\frac{1.15\,R\,i_1}{C}$

The general equation for any voltage e at the rotary is (assuming proportionality between the electromotive force and the magnetomotive force over the small range in voltage considered):

$$F_0\frac{e}{e_n} = F\frac{e}{e_n} + i\,p\,T + \frac{1.15\,R\,i_1}{C} \quad (16)$$

At no load, $e = e_n$
$i = 0$
$i_1 = i_n$

We then have $F_0 = F + \frac{1.15\,Ri_n}{C}$

therefore $i_n = \frac{C}{1.15\,R}\,(F_0 - F)$

At full load, $e = e_f = ke_n$
$i = C$
$i_1 = i_f$

whence we get $kF_0 = kF + CpT + \frac{1.15\,Ri_f}{C}$ (17)

therefore $i_f = \frac{C}{1.15\,R}\left[k(F_0 - F) - CpT\right]$

Substituting the values previously derived for i_f and i_n, and solving for the two unknown quantities F and T, we can determine the proper proportion of shunt and series field to give the required no load and full load voltages, and having determined these, it is readily possible to see what change of voltage occurs with load on the converter.

---

* For part V of this article see May issue

To simplify the equations we will denote

$$\frac{e_n^2(k^2-1)+2ke_nCr+C^2z^2}{2e_nx(1+k)} \text{ by } A.$$

Then $i_f = -A$

$i_n = A$

Substituting these values we get:

$$A = \frac{C}{1.15R}(F_0 - F), \text{ whence } F_0 - F = \frac{1.15RA}{C}$$

and $F_0 - F = \dfrac{1.15RA}{C}$.

$$-A = \frac{C}{1.15R}\left[k(F_0-F) - CpT\right]$$

therefore

$$-\frac{1.15RA}{C} = k\left(F_0 - F_0 + \frac{1.15RA}{C}\right) - CpT,$$

$$-1.15RA = 1.15RAk - C^2pT$$

$$T = \frac{1.15RA(k+1)}{C^2p}$$

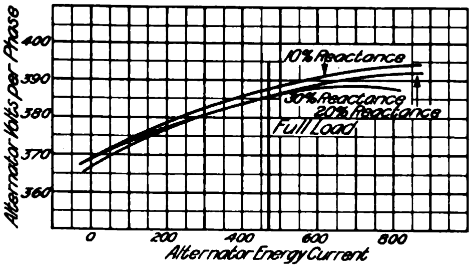


Fig. 19

Examples

Assume that the 300 kw. rotary previously discussed is to operate over a line of 10 per cent. resistance and 20 per cent. reactance, and that the rotary shall over-compound 5 per cent. The problem is to determine the proper adjustment of the shunt and series fields.

Let the no load direct current voltage be 600; then the full load voltage = 1.05 × 600 = 630 volts.

$F_0 = 6300$

$R = 3820$

$p = .945$

$C = 470$ amps.

$e_n = .615 \times 600 = 369$ volts.

$r = \dfrac{.10 \times 369}{\sqrt{3} \times 470} = .0455$

$z^2 = .0104$

$x = .091$

$k = 1.05$

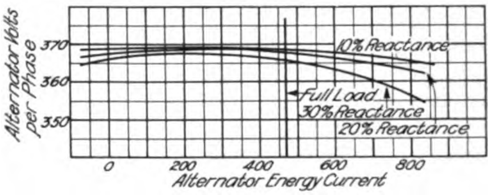


Fig. 20

Then

$$A = \frac{369^2(1.05^2-1) + (2\times1.05\times369\times470\times.0455) + (470^2\times.0104)}{2\times369\times.091\times2.05}$$

$= 236.$

Therefore the full load leading current, as well as the no load lagging current, is 236 amperes, or 50 per cent. of rated current.

The shunt field F at no load is

$$F_0 - \frac{1.15RA}{C} = 6300 - \frac{1.15\times3820\times236}{470} = 4095$$

ampere turns, and the number of turns on the series field $T = \dfrac{1.15RA(k+1)}{C^2p}$

$$= \frac{1.15\times3820\times236\times2.05}{470^2\times.945} = 10.2,$$

In practise 10 turns would be used.

Having determined F and T, the values for these are substituted in equation:

$$F_0\frac{e}{e_n} = F\frac{e}{e_n} + ipT + \frac{1.15Ri_1}{C}$$

which, when solved for i_1, gives the wattless current corresponding to any energy current i.

We then have:

$$i_1 = \frac{C}{1.15R}\left(\frac{e}{e_n}(F_0-F) - ipT\right)$$

e is not definitely known, but the limits e_n at no load and ke_n at full load are known. If the voltage curves were a straight line, then we might write:

$$e = e_n\left[1 + \frac{i}{C}(k-1)\right],$$

and this approximation is quite sufficiently close for all practical purposes.

Thus, in general:

$$i_1 = \frac{1.15R}{C}\left[(1 + \frac{i}{C}(k-1)(F_0-F) - ipT\right]$$

By substituting this value of i_1 corresponding to any value of i, in the general equation:

$$e = -(ir + i_1x) + \sqrt{e_0^2 + 2\,i\,i_1rx - i^2x^2 - i_1^2r^2},$$
we can get not only the value of the constant generator voltage, but the actual rotary voltage at any load.

Substituting the numerical values we get:

$$i_1 = \frac{470}{4400}\left[\left(1 + \left(\frac{i}{470} \times 0.05\right)\right) 2205 - 9.45i\right]$$
$$= 236 - 0.99i.$$

To find the generator voltage (which is kept constant at all loads), substitute in the general equation previously deduced:

$$e_0 = \sqrt{(e + ir + i_1x)^2 + (ix - i_1r)^2}$$

For $i = 0$, $i_1 = 236$.

Therefore

$$e_0 = \sqrt{(369 + 236 \times .091)^2 + 236^2 \times .0455^2}$$
$$= 390.5 \text{ volts.}$$

The results of the calculations for various loads and lines are tabulated below, and the corresponding curves are given in Fig. 19.

For

$i = 0 \quad i_1 = 458 \quad e = 369$:
$i = 200 \quad i_1 = 70 \quad e = 379$:
$i = 400 \quad i_1 = -318 \quad e = 385.7$: 10% resistance
$i = 600 \quad i_1 = -706 \quad e = 391$: 10% reactance
$i = 800 \quad i_1 = -1094 \quad e = 394$:

$i = 0 \quad i_1 = 236 \quad e = 368.8$:
$i = 200 \quad i_1 = 39 \quad e = 377.5$:
$i = 400 \quad i_1 = -159 \quad e = 384.2$: 10% resistance
$i = 600 \quad i_1 = -356 \quad e = 389$: 20% reactance
$i = 800 \quad i_1 = -554 \quad e = 391.9$:

$i = 0 \quad i_1 = 170 \quad e = 367.2$:
$i = 200 \quad i_1 = 26 \quad e = 377$:
$i = 400 \quad i_1 = -118 \quad e = 383.7$: 10% resistance
$i = 600 \quad i_1 = -263 \quad e = 387.6$: 30% reactance
$i = 800 \quad i_1 = -407 \quad e = 388.2$:

It is interesting to note that up to full load the curve is very straight, so that it seems possible to obtain almost perfect control over a wide range of lines, varying from 10 per cent. resistance and 10 per cent. reactance to 10 per cent. resistance and 30 per cent. reactance.

A similar set of curves are shown in Fig. 20. Here the phase control is for constant voltage; that is, $k = 1$. It will be seen that there is a slight bend in the potential curve, very much like that obtained with direct current generators.

The control is very satisfactory, however, up to a certain over load.

The curves show that too much reactance in the line is objectionable, since the control becomes unsatisfactory at overloads.

THE SCHENECTADY SECTION A.I.E.E.
SEASON OF 1907-8

The season of 1907–8 of the Schenectady Section A.I.E.E. closed on May 16th, at which time the final lecture of the year was delivered.

Throughout the season the successful policy of the preceding year was continued, twenty-one regular meetings being held at ten of which the members were addressed by visiting speakers, the platform being occupied upon the other occasions by local engineers. The following is a list of the Season's lectures:

Transient Phenomena in Electrical Circuits, by Dr. C. P. Steinmetz; The Use of Electricity in Steel Mills, by W. T. Dean; Twenty-five Years with the A.I.E.E., by T. C. Martin; The Steam Turbine, by W. L. R. Emmet; Niagara Falls Hydraulic Power and Manufacturing Company, by George R. Shepard; Some Features of Heavy Locomotive Design, by S. T. Dodd; Patents, by A. G. Davis; Electric Furnaces, by C. F. Lindsay; Work of Reclamation, by A. P. Davis; The Re-development of Water Power, by Robert E. Horton; Currency and Finance, by Henry W. Darling; The Influence of Geology on the History of Jamaica, by Dr. R. W. Raymond; Curves and Calculations in Railway Work, by E. H. Anderson; Gas Power, by H. H. Suplee; The Design of Steam Locomotives, by C. J. Mellin; Rotary Converters, by E. J. Berg; An Outline of the Management of the Schenectady Works, by G. E. Emmons; With Lieut. Peary on his First Arctic Expedition, by Langdon Gibson; Navigating the Air, by Augustus Post; Fuel Problems, by Herbert H. Wilson; Alternating Current Underground Distribution, by S. D. Sprong; The Electric Theory of Matter, by Prof. H. C. Jones.

In October, the Schenectady Board of Education gave the Section permission to use the auditorium of the High School for meetings, and this large assembly hall has several times been filled to its utmost capacity by the audiences.

The plan of admitting "local members" to the Section on the payment of a special membership fee was continued with a slight modification, a uniform fee of two dollars per year being adopted. Previously there had been two classes of local members, students in the colleges and employees of the Testing Departments of the General Electric and American Locomotive Companies paying $1.00 per year, and all others $2.00. The adoption of a uniform membership fee not only greatly simplified the keeping of accounts, but increased the revenue to the Section; advantages which were not offset by any attendant detrimental results.

Advance copies of all papers presented at the New York meetings of the Institute were distributed to members of the Section. This courtesy on the part of the Institute was highly appreciated by the local membership.

Throughout the year three smokers were held, which were largely attended, and the expense of which was borne entirely by the local treasury. The first, given on October 10th, was in the nature of a reunion for the old members, and an introduction to the work of the Section for many prospective members. Henry G. Stott, President; Chas. F. Scott, Past President; Ralph W. Pope, Secretary, and Paul Spencer, Chairman of the Local Organization Committee of the Institute, were present and addressed the members on the work of the Institute and its various sections. On December 20th, a second smoker was held, at which an address was given by Capt. G. F. Folger-Osborne, R. E., of the British Indian Service. The third smoker took place on April 3d, and was wholly of an informal character.

At the beginning of the season of 1907–8 there were 1019 members with the Schenectady Section, of which 744 were "local members," and 275 members and associate members of the National Body. At the close of the present season the roll shows 535 local members and 263 members and associates of the National Body, making a total of 798. The decrease in membership for the past year is due to the financial and industrial depression which has prevented many from joining that would otherwise have done so.

The following treasurer's report shows a very satisfactory financial condition for carrying on the work of the ensuing year.

Balance on hand May 23, 1907..........	$773.58	
Dues collected	1068.00	
Interest, etc.........	29.83	
Total receipts ...	———	$1871.41
Cost of meetings, stereopticon, stenographer, announcements, postage, janitor's service, etc. .	509.29	
Expense of delegate to Niagara Falls Convention	31.73	
Cost of smokers	459.98	
Contribution to Public Library........	50.00	
Total expenses to June 2, 1908. .	———	1051.00
Balance on hand		$820.41

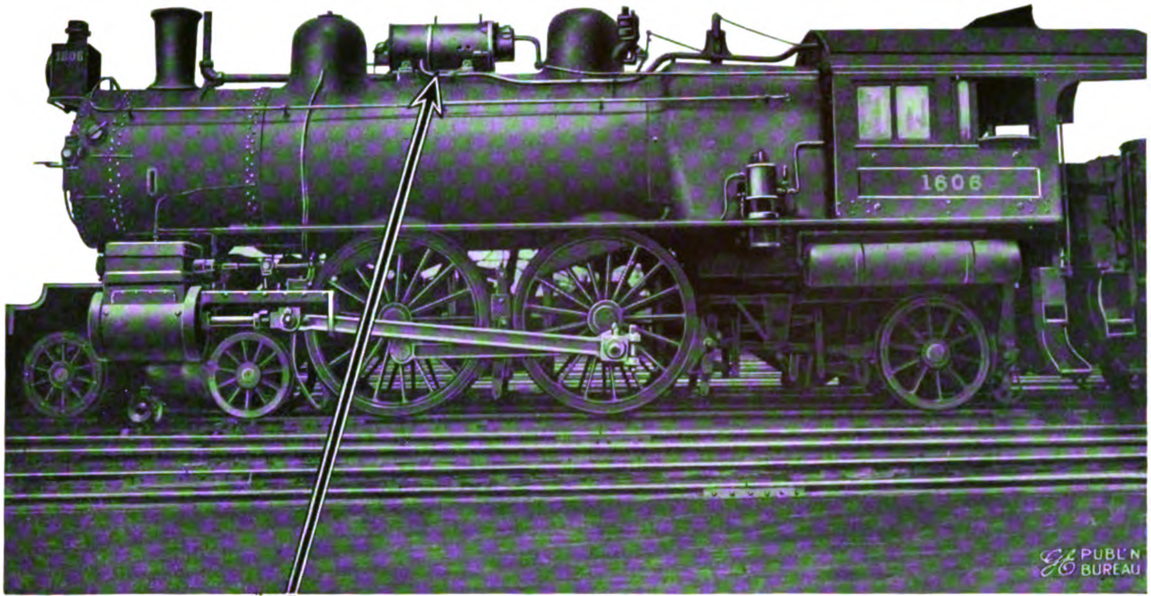
NOTE ON GYROSCOPIC FORCES

In reference to the article on Gyroscopic Forces, appearing in the August and September numbers of the Review for 1907, an error was made in reference to those parts of the article dealing with centrifugal forces. The error arose from ignoring the physical limitations of a mathematical formula for centrifugal force.

The proper formula for this force leads to the result that no additional centrifugal force is produced due to spin; in other words, no gyroscopic centrifugal force exists. The application made in the second part of the article to the General Electric Company's locomotive is therefore wrong, and no additional side thrust on the rails is caused by the spin of the rotating parts of the locomotive. This error also affects the paragraph headed "Vertical Gyroscopic Forces." The total vertical downward force on the outside rails given in the last part of the paragraph should read $\frac{WV^2k^2}{gRrx}$, due to the gyroscopic action, instead of $\frac{3WV^2k^2}{2gRrx}$. In addition, the calculation of the centrifugal force of the body represented in Fig. 11, is incorrect, and the centrifugal force of the disc is negligible, since it is not increased due to spin.

The error in the assumption made for centrifugal force does not affect any other parts of the article, since the value given for the gyroscopic couple is correct, and consequently the applications made therefrom.

W. E. Miller.



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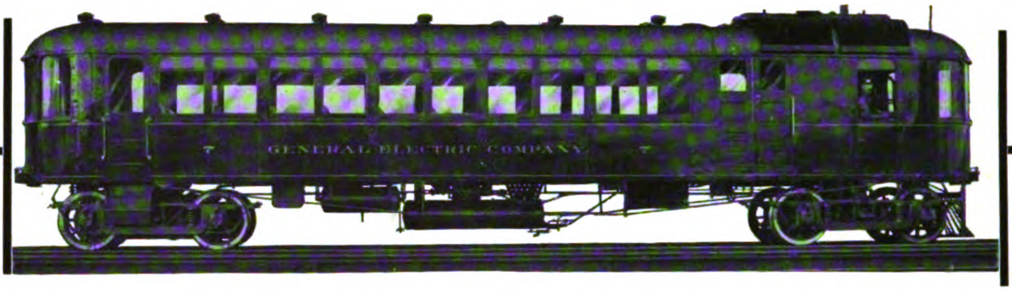

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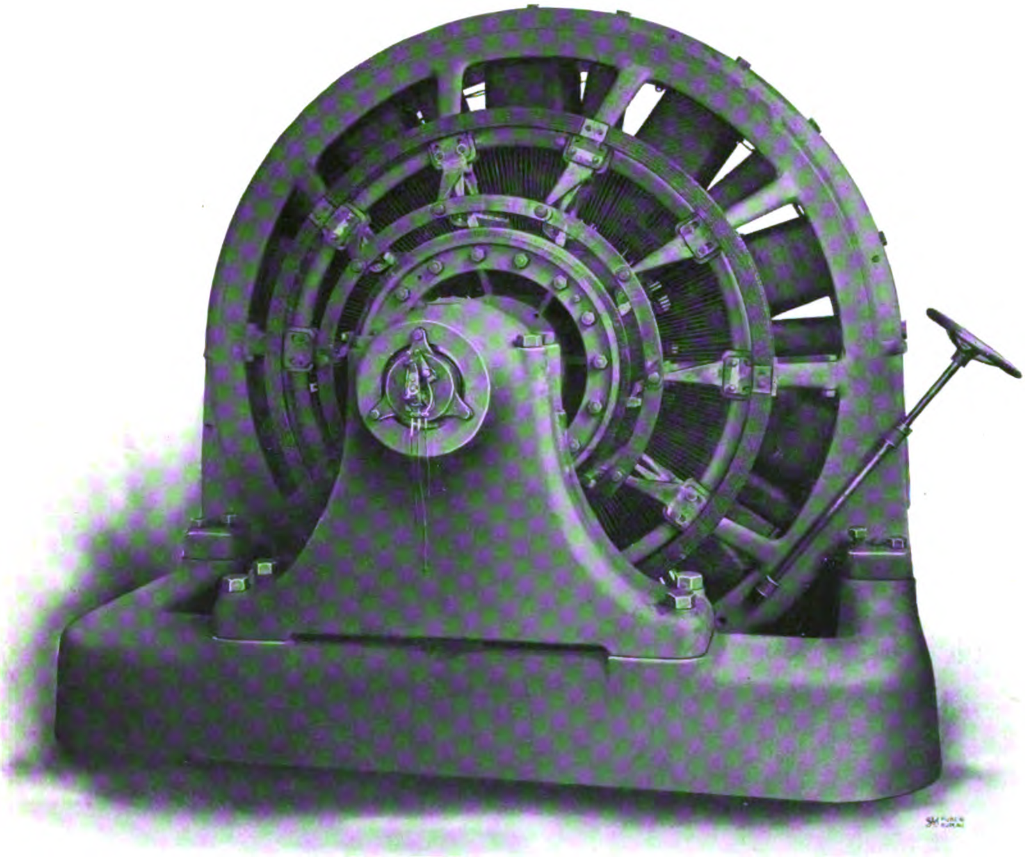

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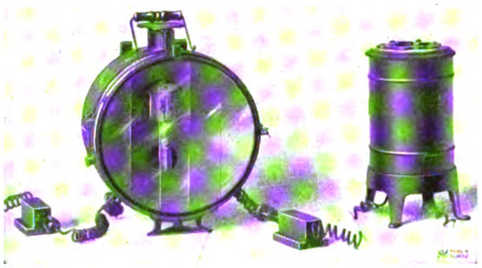

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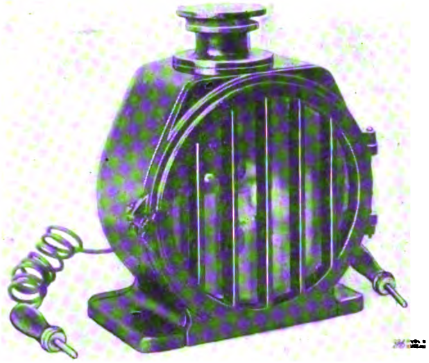

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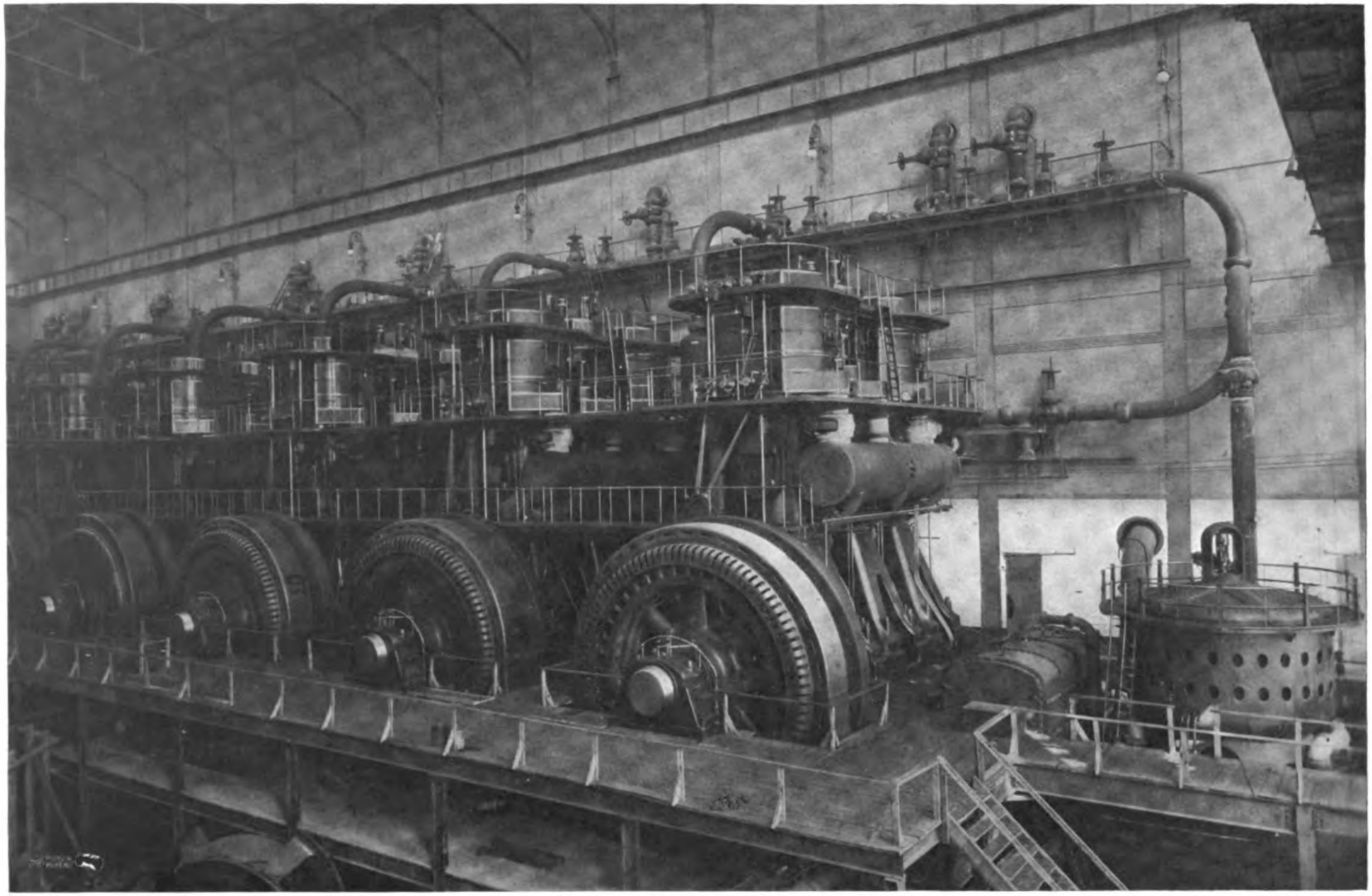

SECTION OF WATERSIDE STATION No. 1, NEW YORK EDISON COMPANY

(See page 51)

GENERAL ELECTRIC REVIEW

ALTERNATING CURRENT UNDERGROUND DISTRIBUTION*

PART I

BY S. D. SPRONG

Many of us who are the later comers in the field of electric light and power distribution, may have unconsciously come to consider the words "early days" synonymous with D.C. constant current series arc lighting and Edison three-wire D.C. distribution. While this idea holds true for a certain period in the beginning of the industry, the alternating current system was given a preliminary test in 1887, and in 1889 started in active competition with the Edison system.

As New York city offered one of the best opportunities for the supply of electric light and power, it was the city to see some of the earliest installations. The Edison system was started in September, 1882; but one of the constituent companies of The United Electric Light and Power Company, which later adopted the alternating current system, began the supply of direct current for arc and incandescent lighting prior to the inauguration of the Edison system. I am unable to state the exact date of the first plant installed by the United States Illuminating Company, for commercial work, but the early records show that a plant had been operated in the Equitable Life Building, 120 Broadway, prior to November 12, 1881. Under that date the Equitable Company advised the Illuminating Company that they would be compelled to discontinue the supply of power for driving the machines owned by the Lighting Company, because their own demands required the full capacity of their steam plant. The machines of the Lighting Company were driven by power purchased from the Equitable Company, but were owned and operated by the Illuminating Company as a commercial lighting plant to supply series arc lamps for street lighting south of Fulton Street, and incandescent lighting for the Equitable Building and other consumers in that vicinity.

While not having to do directly with underground distribution, it may be interesting at this point to briefly review some of the engineering and commercial factors involved in the early development of the system which, by successive changes, became later on a part of The United Electric Light and Power Company.

It should be noted that there has been active commercial and engineering competition in New York city from the beginning of the industry, and that this city appears to have been the "trying-out" place for every new system that was evolved, with its many modifications.

The system developed by Edward Weston was controlled, and the apparatus manufactured by the Weston Electric Light Company. The Weston Company gave the United States Electric Lighting Company exclusive rights for the sale and installation of their apparatus throughout the United States. The United States Electric Lighting Company in turn gave the United States Illuminating Company exclusive control of the Weston system in the city of New York and some of the adjacent counties.

It appears to have been the policy of the Company at that time to establish plants in various parts of the City, and instead of installing their own motive power, to rent power to drive their generators from a plant already installed on the property, paying from $75.00 to $130.00 per h.p. year delivered to their countershaft. It seems that it was not always possible to secure power on the premises where the Company wished to install their electrical apparatus, as is shown by the following extract from a report made in November, 1881:

---

* Lecture delivered before the Schenectady Section, A.I.E.E.

> "In view of the great demand, and consequent scarcity of motive power, and in order to be prepared to furnish facilities for introducing the machines owned by this Company, I deem it my duty to recommend that authority be given at once for the purchase of eight engines of about 20 horsepower, similar in style to the one now being used for lighting the ferry-boat 'Jersey City.'"

I might explain here that, judging from these records, the earliest installation of the Weston system in the vicinity of New York city was made on board the Pennsylvania Railway ferry-boat "Jersey City."

At this time the efforts of the United States Electric Light Company seem to have been about equally divided between selling, installing, and sometimes operating isolated plants; and the installation and operation of larger aggregations of generating units, for street and commercial lighting by the United States Illuminating Company. As an example, the plant on the ferry-boat "Jersey City" was maintained and operated by the selling company.

The engines which the Company was using were of only 20 horse-power, and the generating units were also correspondingly small, a 50-light dynamo being the largest that they manufactured for incandescent lighting, and a 10-light arc machine the largest for arc lighting.

Referring to the arc machines, these supplied series lamps requiring 25 amperes at 20 volts, and sometimes as many as five machines were operated in series on a 50-lamp circuit. It sometimes happened that a machine would reverse, and to detect this promptly, the operators adopted the method of hanging a piece of iron pipe on one of the field poles; so that in case of demagnetization or reversal, the fall of the pipe on the floor would attract the operators' attention. For the regulation of the output of these machines, no ammeters or other instruments were provided, nor did the generator itself have any means of control, by either field rheostat or shifting of the brush-holder. Each circuit, however, had a pilot arc lamp in the station, and there was also in each circuit a large iron wire rheostat with various loops in which a flexible lead could be engaged to cut in or out more or less of the rheostat as the number of lamps on the circuits varied; these changes being made as were judged necessary by the operator from the appearance of the pilot lamp. The drop across the whole of this regulating rheostat equalled the potential of one machine; therefore, when it was found that by degrees all the rheostats had been cut in, a generator was cut out of the circuit, and the rheostat again short circuited. Some form of regulator with a wide range was necessary, because a considerable portion of the street lamps were cut out at midnight. These "half-night" lamps, as they were called, were on the same circuits with "all-night" lamps, making it impossible to extinguish them independently by circuits.

Referring to the incandescent lighting generators, they were, as already stated, of a maximum capacity of 50 lamps. The lamps were of about 16 candle-power, and burned seven in series across 100-volt mains.

The generators were regulated by means of a shunt field rheostat, which was manipulated by hand whenever the red or white lamp of the indicator lighted up. There was a balanced relay connected to the lamps in such a way that a rise of voltage would light the red lamp, and a drop of voltage, the white lamp.

Of course all distribution in New York was overhead, and continued so for some years, or until 1889. About this time a trial section was put underground, in the triangle bounded by Broadway, Sixth avenue and Twenty-third street. This was done with the distinct understanding with the City that it was to be an experiment. The Company desired to carry this trial run over a period of at least a year, as they had doubts as to its reliability for both summer and winter service as compared with overhead construction. That the underground system at that time was, in fact, subject to some disturbances peculiar to itself, was soon discovered. Referring to overhead distribution, I might anticipate a little to mention here that in about 1882 a plant was established at Twenty-seventh street and Sixth avenue, the lines from which ran entirely on the roofs of stores and houses. These, however, were shortly removed because of fire department regulations. On this question of regulations, I note in the records of a meeting held in 1882 that one of the reasons, set forth by some for their refusal to buy the Company's plants, was: "........the inability of the Company to com-ply, in many essential points, with the requirements and rules of the Board of Fire Underwriters, which have, from time to time, been altered and amended." Another explanation given in this report was, "........the belief of those desirous of using electric light that they would be furnished from outside circuits, at less expense than they could operate them for themselves." Public sentiment has changed considerably since that time.

It is interesting to consider for a moment the rapid growth of the electric lighting industry during this early time. The records show that in 1882 this Company alone had eight small stations in operation, supplying 590 arc lamps, mostly for street lighting, and about the same number of incandescent lamps. It also had 109 miles of wire in use. In the matter of prices, it was receiving from the City 70 cents per lamp per night, or about $255.00 per lamp per year. Incandescent lighting was done at the flat rate of $3.00 per lamp per year, including free lamp renewals. It appears to have been clearly recognized at that time that the price for incandescent lighting was not a competitive one with gas, as I may quote from one of the records, that:

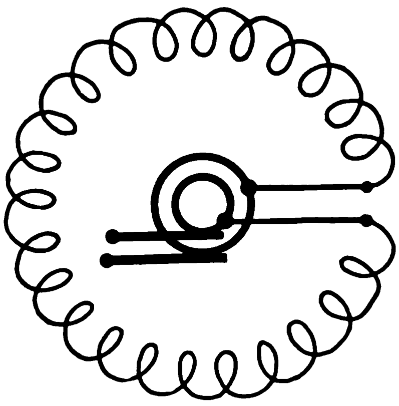

Fig. 1. Diagram of Single-Phase Alternator

"Such incandescent lighting as the Company will be able to furnish from its various stations can be disposed of at rates which will in no sense be in competition with gas, and in many instances, a large percentage on the price of gas will be cheerfully paid."

From this very general review of the Company's affairs at that time, it is to be inferred that the engineers did not see their way clear to undertake the general distribution of incandescent lighting on most of the streets of the City, as they had restricted themselves to installing an incandescent lighting plant in the immediate vicinity of one or more large consumers, such as large office buildings, the public markets, etc. A recognition of their engineering limitation appears to have prompted the following, which is quoted from the records of their annual meeting for 1883:

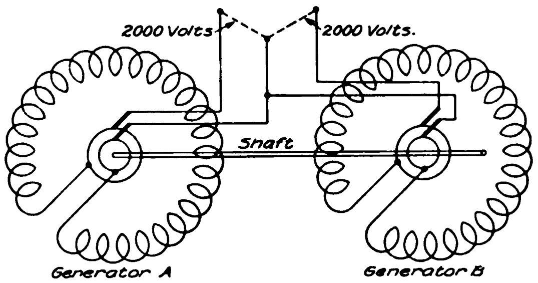

Fig. 2. Diagram of Two Single-Phase Alternators with Armatures Mounted on same Shaft

"........it is not intended to attempt a general distribution of incandescent lights, still, the supplying of large establishments which burn a considerable number of lamps at long serice, is not only possible, but can be done at rates profitable to the Company........"

It should be kept in mind that at about this time the Edison three-wire system was in operation, enabling the competing Company to economically distribute current for incandescent lighting over a much larger area than could the United States Illuminating Company, a fact that placed the competitors of the latter concern in a decidedly superior position.

The United States Illuminating Company continued to extend its business, principally along the lines of street and interior arc lighting, the Edison three-wire system in the meantime making relatively great advance, both commercially and as to territory covered.

That this matter was recognized to be of pressing importance to them, is reflected in the following quotation from the records of a meeting in 1888:

"As you are doubtless aware, it is by this method (A.C.) of supplying incandescent lights that we expect to hold our customers in the district—now threatened by an early and bitter competition with the Edison system."

As these questions have long since lost all their commercial significance, I think we should stop for a moment to again remind ourselves of Edison's early and complete grasp of the whole engineering situation, as shown not only by subsequent practice, but more especially by the methods of his early contemporaries.

From these considerations, we can appreciate with what interest the high voltage alternating system was taken up for consideration on its appearance in 1887. While it meant a radical change in the Company's incandescent system, yet it promised to remove the serious engineering handicap under which they had been laboring, and to permit them to handle the natural growth of this line of the business, by taking on consumers with little regard to their distance from the generating station.

The Company finally decided to change over their incandescent lighting system from the D.C. to the A.C., and the first commercial alternating current lighting in New York city was done in 1889. As we consider the early alternating current system, I wish to emphasize the fact that, whereas the Edison three-wire system had at this time no important problem unsolved, except the question of quality and cost of incandescent lamps, the engineers of the alternating system were confronted, not only by the lamp problem, but in addition by a number of new and perplexing questions. Among these were questions of generator design, such as regulation; and, more important, the matter of insulation. The first A.C. machines were of 1500 lights capacity, single-phase, 1000 volts, 133 cycles; the armatures having smooth body and "pancake" coils. The next step was the introduction of generators of similar characteristics, but having 3000 lights capacity. These were followed by generators to supply the same service, but having toothed armatures, and a capacity of 4000 lights.

At this time all distribution was still overhead, and while arc circuits were considered as high tension, they could be avoided by the linemen because they seldom occupied the whole pole capacity, and few of them were operated in the daytime. When it came to operating 1000-volt A.C. lines continuously, it introduced a question as to the safety of the linemen and the general care of the feeders. Problems of the same order had also to be met in the installation of high voltage lines and converters on the customers' premises, and in the design and installation of switches and fittings for properly handling this voltage. The greatest problem, however, was the one of transformers, as the art of transformer design and insulation may be said to have hardly begun. The first transformers were, of course, air-cooled, and built in various capacities up to a maximum of 40 lights. If an installation required more than 40 lights, additional transformers were installed, the secondaries all feeding in multiple to the building mains. Some of the larger installations at this time required a great number of transformers to supply the demand, thus necessitating a large area to be set aside exclusively for their use. The more usual method was to attach the transformers on the outside of the building, no transformers being installed on poles. The primary switches used at this time were of the ordinary "snap" variety in general use on the 100-volt house circuits.

Referring again to the generators, the first single-phase machine, which has already been described, is shown diagrammatically in Fig. 1.

The next advance in design was made in 1893, and embodied two single-phase, 2500-volt, 60-cycle machines, with armatures on the same shaft (Fig. 2) displaced 90 electrical degrees. These machines were used only single-phase.

The next step was made in 1896, when a pair of two-phase, 300-volt, 375 kw., 60-cycle units, made up of two single-phase machines mounted on a common shaft, were operated in multiple. (Fig. 3.) The single-phase winding had a smaller capacity "teaser" winding connected to the middle of the main winding, giving a two-phase relation on a third conductor. Both teaser windings were connected in multiple. These units were driven by vertical compound condensing engines directly connected to the generators. It was at this time that the Company did its first two-phase power work, the first installation comprising a 15 h.p. pump motor having a wound rotor and short-circuiting rings.

The next and final step in this development was made in 1897; it was a single machine of 750 kw. capacity, having a closed circuit, two-phase, 3000-volt winding. (Fig. 4.) After March 1898, these machines were all operated in multiple on the same bus. This appears to have been the first A.C. system to adopt multiple operation. The factor which made it practicable at this time was the distinctly better regulation of the 1897 generators. Contrasting with the uncertainty with which multiple operation was approached at this time, I might anticipate a little to state that a few years later the following miscellaneous apparatus was in regular multiple operation on this system, *viz.:*

Eight 750 kw. direct connected generators; three 400 kw. belt connected generators; and 2 sets of 2500 kw. transformers operated from the 60-cycle Waterside bus and 5 motor generators, making a total of 3800 kw. from generators driven by induction motors connected to the 25-cycle Waterside bus.

Referring again to the 1897 machines, these were connected to buses made up of four conductors, from which the various circuits were so tapped as to distribute the load on the armature winding as shown in Fig. 4. This method balanced the load on the whole armature winding, although the middle two-phase feeder conductor probably never carried more than 10 per cent. of the total load on the feeder.

To make this clearer, I will explain here the method of distribution. Three-phase current at 7500 volts is received in the substations from Waterside and stepped down by T-connected transformers to 3000 volts between the outer conductors of a three-conductor, two-phase bus. This gives about 2100 volts on each phase, between the center conductor and the outers. The system may be properly classed as a two-phase, three-wire, but with a number of qualifications. The feeders are made up of three 250,000 c.m. conductors, and reach the approximate load centers of their particular districts. From the load center, distributors of smaller area, some of three and some of two conductors, are carried as mains to the various parts of the district; the two-conductor primary being used where only lighting is required, and the third conductor where power is also used.

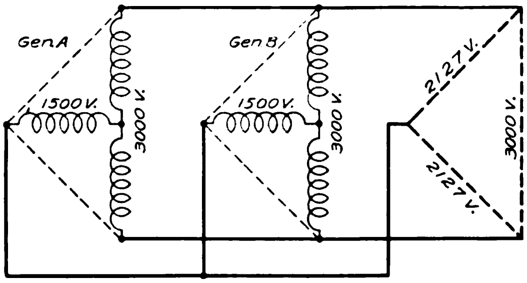

Fig. 3. Diagram of Two Single-Phase Alternators with "Teaser" Winding, Connected in Multiple

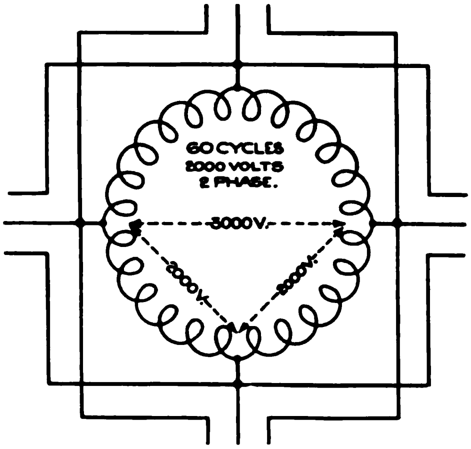

Fig. 4. Diagram of Closed Circuit Two-Phase Alternator

While the system is a three-wire, two-phase one, it is, in fact, a single-phase system so far as the lighting load is concerned. This will be clearer, perhaps, if we start from the Waterside generators and show the main circuits and transformations. (Fig. 5). As shown in this figure, the generating equipment at present consists of one Curtis turbo-generator of 5,000 kw., 7500 volts, 3-phase, 60 cycles, located in Waterside No. 1 (see cut on page 50); and two turbo-generators, each of 7500 kw. 7500-volt, 60-cycle, 3-phase, located in Waterside No. 2; all three units operating in multiple on the 60-cycle bus in Waterside No. 2. It will be noted that in the turbo-units of Waterside No. 2, the 60-cycle generator is the second machine in a tandem combination of a 25-cycle, 3-phase, 6600-volt, 7500 kw. generator mounted next the turbine and on a common shaft with the 60-cycle machine. The 25-cycle generators operate on the common 25-cycle bus, and therefore in multiple with the other generators in these stations. The nominal capacity of the turbine is 7500 kw., with the usual overload margin, and it was not intended, in making up these tandem units, that the turbine should be of a capacity to deliver full load from both generators simultaneously. It has become general practice, however, to operate both generators at the same time, each delivering current to its respective bus.

This is the condition under which the generators are operated for about eighteen hours a day; *i. e.*, from about 11 p.m. until about 4 the following afternoon. With the 25-cycle generator in operation, this gives 62½ cycles from the other generator, which is nominally a 60-cycle machine. Therefore, our system is operated at 62½ cycles during the hours above indicated, and we have had no serious complaints from our consumers because of this slight increase in frequency. Our system would, in fact, be operated at 62½ cycles during the whole 24 hours were it not for the fact that we have, at both substations, a number of 25-cycle, induction motor-driven, 60-cycle generators, which operate in multiple on the same substation bus with the secondary side of the transformers supplied from the 60-cycle generators in Waterside. As the slip of the induction motors is from 2½ to 3 per cent. it is necessary, when using the motor generators, to uncouple the 25 and 60-cycle systems, allowing the latter to lower its frequency to about 60 cycles.

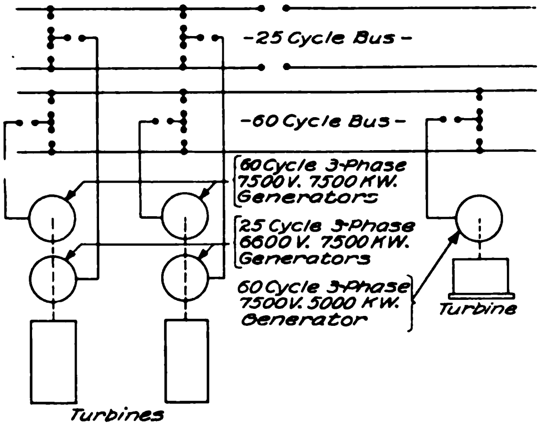

Fig. 5. Diagram Showing Connections Between Alternating Current Turbo-Generators in Waterside Stations

One substation has two 1000 kw. motor generator sets, and the other, two of 1000 kw., and two of 400 kw. The motor generators in the latter station have been operated for some time as "rotary condensers," by running the generator as an over-excited synchronous motor and controlling the field with a General Electric Type TA regulator. A great improvement in regulation is secured by this arrangement, as the substation is over seven miles from Waterside.

The motor generators are held largely as reserve, and they must, for this reason, be always in a position to carry load during the hours of maximum. Therefore, the 25- and 60-cycle systems remain separated from about 4 p.m. until over the peak load, so that the motor generators may be instantly available if necessary. It is the general practice to operate at least two 60-cycle generators at all hours, regardless of the load demand, the third generator being used over the peak. This condition, of course, results in the 60-cycle generator being, at some hours of the day, very much underloaded. If they were single generator units, this would mean low steam economy; but because of their combination with the 25-cycle generators, and the fact that during the hours of light load the systems may be coupled, the margin of load not required from the 60-cycle generator is taken from the 25-cycle machine, thus bringing the load on the turbine—and hence the steam economy—up to a favorable point.

There is another advantageous feature in this double unit combination, which is, that in case of trouble with the turbine end, or any of the auxiliaries, making it inadvisable to operate the unit as a prime mover, the coupling between the 25-cycle generator and the turbine may be disconnected, thus allowing the 60-cycle generator to be driven by the 25-cycle machine, operating as a synchronous motor. This is not a theoretical consideration alone, as it has actually been worked out in practice; including, what may appear at first impracticable, the ready starting of the motor generator from standstill. The starting of this unit, was arranged for in a very simple way. A separate section of the 25-cycle bus was made dead, and to this was connected the 25-cycle end of the unit (which may now be considered as a motor), and an independent 25-cycle turbo generator, both at standstill. The fields of both motor and generator were then closed, and on starting the turbo unit, the motor and its 60-cycle generator remained in step and were brought up to speed, the separate section of the 25-cycle bus being afterward synchronized and closed on to the regular bus. This method was carried out without difficulty, and was shown to be thoroughly practical.

As already stated, the 60-cycle current is generated 3-phase, 7500 volts in Waterside, and transmitted to the substations over 250,000 c.m., 3-conductor cables. Here it is transformed to the distributing voltage of the substation (2100 volts per phase, or 3000 volts across the outer conductors), air blast static transformer sets, made up of a combination of one 2500 kw., and one 250 kw. transformer, being used for the purpose. (Fig. 6.)

The small transformer, having only 10 per cent. of the capacity of the other, supplies the third, or power leg of the system, and maintains the proper phase relation for power work. As our power load is only about 15 per cent. of our maximum, a transformer of this capacity is sufficient for the purpose. The larger transformer of the set has a terminal voltage of 3000, which is the pressure across the hypothenuse of the two-phase angle. It is on the outer conductors, at this voltage, that all the lighting load is carried, as is also half of the power load. Connecting the lighting load across the outer conductors in this way results in a very marked advantage, in that it transmits what is the bulk of our load at a much higher voltage than if we did lighting from the phases independently. This arrangement has another important advantage in addition to the one noted; namely, that it is necessary to regulate what is, in effect, but one phase. Fig. 7 shows the connections and range of the regulators. As before stated, the feeders consist of three 250,000 c.m. conductors, permitting a load of about 250 amperes at 3000 volts. Each feeder has a 2-phase motor operated induction regulator of 85 kw. capacity, giving 10 per cent. voltage range on either side of normal. These regulators are connected 2-phase, boosting or depressing the voltage equally on the outer legs of the circuit.

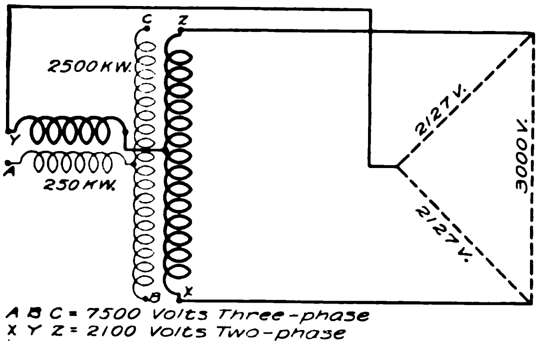

Fig. 6. Connections of Transformers in Substations

Of course, we are aware that, as our load is so largely single-phase, the three-phase side is distorted, and to some extent, the two-phase secondary side also. This distortion, however, has been of no consequence in our power work. The distortion varies through a limited range, with the load; but to keep the phase angles as nearly correct as possible, we have shifted from the true center, the point where the power transformer taps the primary of the large lighting transformer. This change largely eliminated the distortion as measured at the substation, the motors themselves maintaining practical equality of phases on the distributing system.

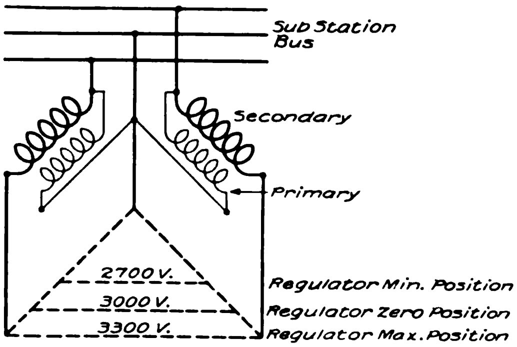

Fig. 7. Connections and Voltage Range of Feeder Regulators

All the lighting is done single-phase across the outer conductors at 3000 volts. For two-phase power work, two transformers are used, which are connected in the same manner as the large step-down transformers in the substations. Fig. 8 shows the primary and secondary transformer connections. All transformers, whether for lighting or for power work, are similar; *i. e.*, the primaries and secondaries are in two sections. As is shown, the transformer which is connected across the outers, has its two primary sections (1500 volts each) in series. The other has its primaries connected in multiple, as the voltage between the power conductor and the middle of the main transformer is just one-half the voltage across the outers. The secondaries are connected to give 200 volts, two-phase; and while the phases are independent, they are run three-wire to the motors. It will be noted that in this combination, one-half of the power load is also carried at the higher voltage, or 3000 volts.

Single-phase service may have some drawbacks when carrying so large a percentage of the total load, but these are not sufficient to offset the important advantages obtained by distribution at the higher voltage.

Considering for a moment some of the details of the installation on the customer's premises, the question of primary switch and fuses for the individual transformers required some special consideration. The first form of switch used was the ordinary low-voltage "snap" variety, but it seems hardly probable that this switch was ever expected to be an adequate one for the purpose. Following this, a boxed-in, open-air type was developed that could be operated safely by means of a cord and wooden rod. The next and final type was an oil switch designed by the Company for its special use. This switch is inexpensive, and safe for both the operator and the system.

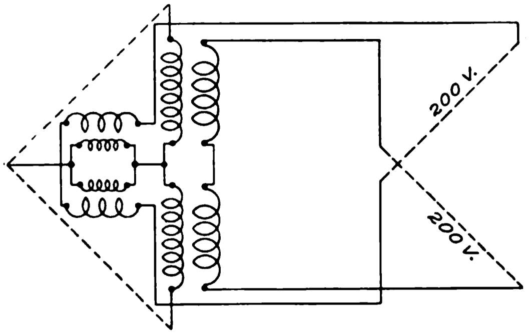

Fig. 8. Connections of Transformers for Two-Phase Power Work

The problem of fuses, however, was not so easily worked out. Omitting details, the special fuse block combination shown in Fig. 9 was finally evolved; it consists of a solid porcelain block containing two compartments separated by a barrier, and having two brass connecting blocks mounted in the bottom of each of these compartments. The conductor is first soldered into a long swivel sleeve, which in turn is secured by a screw cap to the projecting threaded terminal of the block attached to the base. The screw cap is attached to and set up by means of the projecting hard rubber tube handle, which covers all live parts. It will be noted that this rubber handle projects beyond the cap, thereby protecting anyone from accidental contact with the latter when it is disengaged for any purpose. By the side of the tube handle surrounding the cable end is a solid rubber handle carrying on its inner end a fixed tap bolt. On this tap bolt, and next to the handle, a freely revolving cup-shaped, unthreaded nut is carried. Between this nut and the one on the opposite side of the barrier—which is the terminal going to the transformer primary—is an aluminum wire of such cross-section as will carry 20 amperes continuously. As this aluminum conductor cannot be soldered to the terminals, a copper wire of somewhat larger cross-section is twisted with it from a point near the center of the fuse. A sufficiently good contact between the copper and aluminum wires is secured by this arrangement. This combination terminal is soldered into a groove in the terminal nut, and is carried by the latter. The copper conductor is carried down the fuse wire to insure the blowing of the fuse at its center, opposite the porcelain partition. It has always operated successfully, no arc being maintained around the partition between the terminals. The fuse wire and its copper terminals are enclosed first in a thin rubber tube, this tube in turn being enclosed in a thick rubber tube of considerably larger diameter. Because of the more rigid character of the outer tube, it is slitted at the bend, thus permitting the escape of gas, but otherwise affording good mechanical protection to the fuse wire.

Some of the advantages of this fuse block are, that it is inexpensive, and perfectly safe, both as a fuse and to those working around it. This latter is an important point, as it was no inconsiderable part of the problem to develop a fuse block which effectively guarded against accidental contact, both when the fuse was in position and after the fuse had blown. It is only by deliberate intent that contact can be made with any of the live parts. A fuse may be easily and safely removed, or the terminals disconnected, without the use of a torch. All contacts are of ample area and may be made positively tight without the use of a wrench or screwdriver, or even the precaution of rubber gloves.

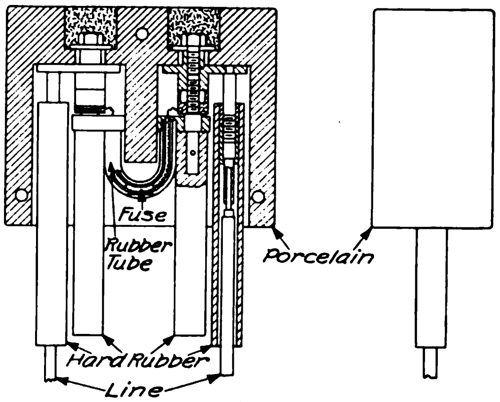

Fig. 9. Fuse Block

(To be continued)

SPLIT POLE CONVERTERS

By J. E. Woodbridge

The ratio of the D.C. voltage to the A.C. voltage of an ordinary rotary converter is practically invariable. To give local control of the D.C. voltage in lighting substations, independent of the A.C. voltage as determined by the main station, it is customary to use induction regulators or A.C. boosters, or in some cases voltage varying dial switches connected to taps in the transformer windings. In railway work, where the required range of voltage control is less (only enough being wanted to take up A.C. drop and thereby deliver constant voltage), it is customary to use series reactance, and to vary the wattless component with the load, thereby varying the delivered A.C. voltage and consequently the D.C. voltage, at the expense of a varying power factor.

The split pole converter, recently brought out by the General Electric Company, gives a means of varying at will the ratio of the D.C. voltage to the A.C. voltage, thus doing the work of induction regulator, booster, or other voltage varying apparatus, by the variation of field excitation only, without devices for voltage variation external to the converter, except an additional field rheostat or other field controlling device. The field excitation may be varied by hand or automatically, as desired. The automatic variation may be carried out, of course, either by compound windings responsive to the load, or by automatic regulators responsive to voltage.

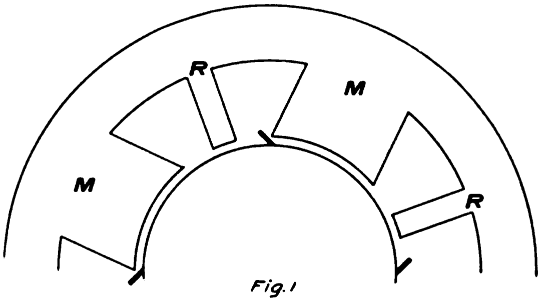

Fig. 1

Explanation of Principle

Consider a converter with a field structure as shown in Fig. 1, resembling in appearance a machine with commutating poles, but with the brushes so set that one of the interpoles, or regulating poles as they are called in this case, adds its flux to that of one main pole, cutting the conductors between two direct current brushes. In this figure the regulating pole has been shown with a width equal to 20 per cent. of that of the main pole. To obtain definite figures, it will be assumed that this machine at normal speed, with the main poles excited to normal density, but with no excitation on the regulating poles, gives 250 volts D.C. Then with each regulating pole also excited to the same density as the main poles, and with a polarity corresponding to that of the main pole in the same section between brushes, the D.C. voltage will go up to 300 at the same speed, since the total flux cutting the conductors in one direction between brushes has been increased 20 per cent. If, on the other hand, the excitation of the regulating poles is reversed and brought up to the same density as that of the main poles, the D.C. voltage will fall to 200, since in this case the regulating poles give a back e.m.f. opposing 20 per cent. of the forward e.m.f. generated by the main poles.

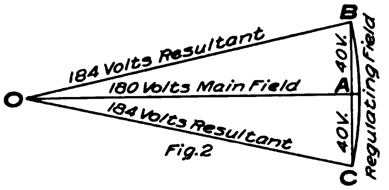

Fig. 2

Now, if this machine is assumed to be equipped with collector rings also; *i. e.*, if it is a converter, it will be found that this method of varying the D.C. voltage from 200 to 300 will not give anything like as great a variation of the A.C. voltage; in fact, the A.C. voltage will be the same when delivering 200 as when delivering 300 D.C., if the main field excitation is the same. This may be seen by reference to Fig. 2, which is a vector diagram of the A.C. voltages developed in the armature winding by the two sets of poles. The horizontal line *OA* represents the A.C. e.m.f. generated by the main poles alone, with the regulating poles unexcited; that is, when delivering 250 volts D.C. This, for a six-phase converter, amounts to about 180 volts diametrical, or between electrically opposite collector rings. If now the regulating poles are excited full strength, to bring the D.C. pressure up to 300 volts, the A.C. voltage generated by the regulating poles will be 90° out of phase with that generated by the main poles, since they are spaced midway between the main poles, and will be about 40 volts, as shown by the line *AB*. The resultant *AC* volts across the collector rings will be represented by the line *OB* and equal to 184. If, on the other hand, the regulating poles are reversed full strength to cut the D.C. voltage down to 200, the A.C. voltages of main and regulating poles will be *OA* and *AC* respectively, giving the resultant *OC* equal to *OB*, that is, 184. This means that the D.C. volts may be either 200 or 300 with the same A.C. volts, and if the main field is kept constant, the D.C. volts may be anything between 200 and 300, the A.C. varying only between 180 and 184. No variation whatever of the A.C. volts, with full range of D.C. volts, may be obtained by so strengthening the main field, as the regulating field is weakened, as to give a resultant always equal to *OB;* that is, to swing the end of the resultant, as shown in Fig. 2, from *B* to *C* through the circular arc *BC*. Of course, this will make *OA*, or the main field strength, equal to *OB* when the regulating field is unexcited, and will not give 250 volts D.C. under this condition, but about 256, with 250 at another adjustment. This method of operation will give unity power factor with a constant impressed e.m.f. of 184 volts A.C., with a range of D.C. voltage from 200 to 300 volts. It is obvious that if the regulating poles are made of the same cross-section as the main poles, a machine might be made in this way to give a D.C. pressure varying from nothing up to its maximum, with constant impressed A.C. voltage.

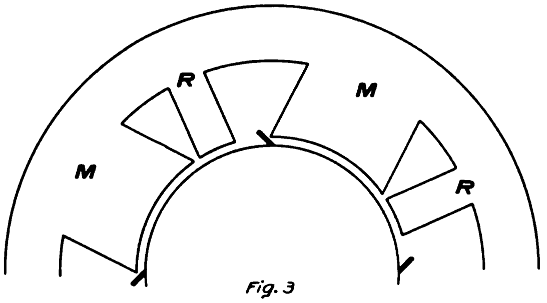

Fig. 3

In practice, up to date, no machine has been built quite like that shown; that is, with regulating poles spaced midway between the main poles, for the following reason: Such a construction involves a dead space between main and regulating poles equal in span to the neutral space provided for commutation. This space should be at least one-fifth of the pole pitch; that is, one-fifth of the circumferential distance from the center of one main pole to that of the next. This means that the ineffective turns, or the turns not generating voltage, will be increased by one-fifth of the total number, over and above those of a converter with one-piece poles, for the same D.C. maximum voltage. Or, to put the matter in another way, if the regulating pole of such a machine is consolidated with the main pole by omitting the space between them, the same flux density will generate the same D.C. pressure with a 20 per cent. reduction of the armature diameter. That is, the division of the pole into two sections symmetrically spaced increases the amount of armature iron 20 per cent., with a somewhat smaller increase of some other parts, such as yoke, frame, etc., the commutator, collector rings, brush rigging, etc., remaining unchanged.

In practice, machines have been made with the regulating pole crowded closer to the corresponding main pole, as shown in Fig. 3. Except for magnetic leakage from the main pole to the regulating pole when the latter is opposed to the former; *i. e.*, when the D.C. voltage is being depressed, the effect on the D.C. voltage remains unchanged by this closer juxtaposition. The effect on the A.C. voltage is, however, quite altered. Fig. 4 shows the effect on the A.C. voltage of varying the regulating field strength of a machine proportioned according to Fig. 3 from a density equal to that in the main poles to

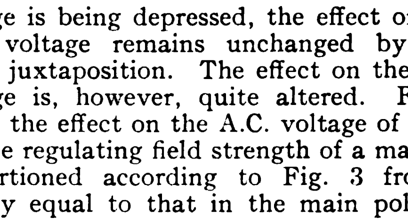

Fig. 4

the same density reversed, the main field strength remaining constant. The D.C. voltage in this case varies from 30 per cent. above that set up by the main field alone to 30 per cent. below, or let us say from 325 to 175, while the A.C. voltage varies only from 200 to 175.

To keep the A.C. voltage constant with such a machine, it is necessary to strengthen the main field as the D.C. voltage is reduced, by weakening the regulating field or by reversing it. This runs up the core loss, particularly on low D.C. voltages (which are rarely wanted), so that it is not customary to work a machine, proportioned as in Fig. 3, through such a range as 175 to 325 volts. We will assume that the range is 240 to 300 volts, and that at the highest voltage both main and regulating fields have the same density, presenting to the armature practically one continuous pole face of uniform flux intensity. The diagram of A.C. component voltages to give constant A.C. resultant voltage across the rings for this case, is shown in Fig. 5. At 300 volts D.C., the main field sets up A.C. voltage OA, and the regulating field voltage AB, with resultant OB equal to about 200 volts A.C. At 270 volts D.C., the main field sets up A.C. voltage OA_1, and the regulating field voltage A_1B_1, giving the resultant A.C. voltage OB_1, equal to OB. Similarly, at 240 volts D.C. the main field sets up the A.C. voltage OA_2, and the regulating field (now reversed) sets up the counter voltage A_2B_2, giving the resultant OB_2 again equal to 200. It will be noted that, theoretically, the main field strength must be increased about 15 per cent. over its value at 300 volts D.C., in order to keep up the A.C. voltage when the regulating field is depressing the D.C. voltage to 240. Since A_2B_2 is about tangent to the circular arc, further depression of the D.C. voltage does not continue to increase the required strength of the main field, which, at a materially lower D.C. voltage, requires weakening to give proper A.C. pressure.

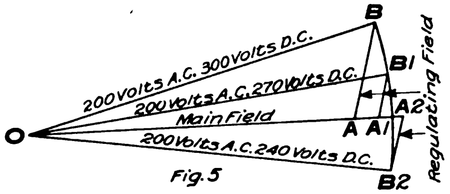
B
B1
A2
A
A1
O
B2
200 Volts A.C. 300 Volts D.C.
200 Volts A.C. 270 Volts D.C.
Main Field
200 Volts A.C. 240 Volts D.C.
Regulating Field

Fig. 5

Wave Shape

Considerable criticism has been aimed at this type of machine on the score of bad wave shape. A wave shape of alternating e.m.f. differing from a simple sinusoid can only be obtained by the presence of harmonics. Even harmonics; that is, harmonics having a frequency of 50, 100, 150, 200, or other cycles in the same progression (assuming that the converter is a 25-cycle machine), cannot be induced in a symmetrical armature winding. The 3d and 9th harmonics; *viz.*, 75 and 225 cycles, can be balanced at the primary terminals by the use of three-phase collector rings, or by the use of the double delta connection or the Y diametrical connection for a six-phase machine. Of other harmonics to be feared, there remain only the 5th and 7th; that is, 125 and 175 cycles respectively. It has been shown mathematically by Mr. J. L. Woodbridge,* Chief Engineer of the Electric Storage Battery Co., that for the construction shown in Fig. 1, the 5th harmonic voltage will not exceed 6 per cent. of the fundamental voltage, and the 7th will not exceed 3 per cent. These values are far less than those of high tension, three-phase, engine-driven alternators or corresponding synchronous motors, with the usual construction of two slots per pole per phase. Such machines have run for years with no trouble from bad wave shapes. The reactance of the armature circuit, and the external series reactance of transformer, network and generator windings, is sufficient to reduce the currents from these high frequency voltages (125 and 175 cycles) to negligible values. For instance, a 10 per cent. reactance at fundamental frequency is a 50 per cent. reactance at the 5th harmonic frequency, and limits the 5th harmonic current from a 6 per cent. voltage to 12 per cent. of full load. This adds only 1½ per cent. to full load I^2R heating. This reduction of higher frequency currents to negligible values is confirmed by oscillograph records from machines proportioned about as shown in Fig. 3.

Commutation

Converters require a small forward lead of the brushes, sufficient to give enough e.m.f. in the turns short circuited during commutation to reverse the current. To obtain this with the split pole converter with reversible regulating poles, it is of course necessary to run the armature from the brushes toward the main poles, or clockwise, as drawn in Fig. 1 or 3; otherwise the commutating fringe would reverse at low D.C. voltages. The weakening of the main field with increasing D.C. voltage does not materially disturb commutation, which appears to be quite as good over the full range of voltage and load as that of standard converters.

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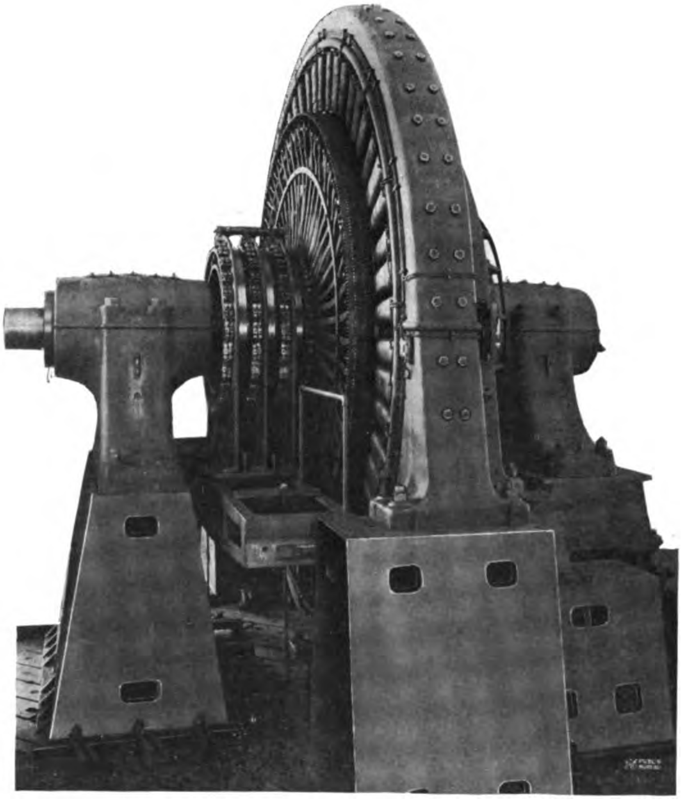
* See Proceedings A.I.E.E., June, 1908.



2000 Kw. Split Pole Rotary Converter

Uses

Machines of this type have thus far been built for 25 cycles only. It would be a difficult matter to crowd in the double field structure for higher frequencies, especially for 60 cycles, without excessive armature peripheral speed. The most notable machine built so far is one rated at 2000 kw. capacity, with a range from 200 to 300 volts. This machine has been built for the Electric Storage Battery Co., who are installing it in the new Gary plant of the Indiana Steel Company, with a storage battery and automatic ratio varying apparatus responsive to changes in A.C. load, such that the battery will discharge on heavy loads and charge on light loads on the A.C. system, relieving the gas engine-driven generating station of that much of the load fluctuations. Thus the machine will work inverted when the battery discharges; that is, at the lower D.C. voltage. This converter has been tested with 14,000 amperes at 200 volts, and 10,000 at 300 volts. Four 1000 kw. machines for lighting work have also been built for the Brooklyn Edison Company, with a range of from 240 to 300 volts.

A 500 kw. machine with a range of 230 to 300 volts has been completed for the Chicago

Edison Company. This machine was tested through a range of 200 to 325 volts, and gave excellent commutation at all voltages and currents up to 50% in excess of full load values; it is also required to carry 150 kw. at 115 volts on one side of a three-wire system deriving the neutral from transformers diametrically connected.

NOTES ON THE DESIRABILITY OF STANDARD SPECIFICATIONS FOR HARD DRAWN COPPER WIRE *

By W. H. Bassett and J. A. Capp.

Until within the last few years, hard drawn copper wire has been used principally for telephone and trolley lines. With the increasing development of hydro-electric plants, where the generating stations are apt to be at considerable distances from the point of application of the power, there has been a rapidly growing use of hard drawn copper wire for the transmission lines; and the time seems ripe for the preparation of specifications for hard drawn copper wire, which shall be fair and reasonable, both from the standpoint of the manufacturer and that of the consumer.

The specifications already in existence agree only in that they all require certain minimum electric conductivity and tensile strength, and that they permit certain variations from nominal diameters. Generally speaking, however, no two of these agree in what should be the minimum permissible tensile strength, or variation in diameter, and many of them include other requirements, such as a minimum elastic limit, a minimum number of twists made in different ways and on different lengths of wire and at different rates of rotation. Most of the specifications require a certain minimum elongation, which is measured in various original lengths and under different conditions. Naturally, it is often the result that in a given specification the attempt has been made to cover all of the apparently desirable characteristics; and it sometimes happens that the maxima in opposed properties are stated as the specified requirements.

The electrical conductivity of the wire is probably the most nearly fixed of all the characteristics demanded; and yet there is an unexpectedly wide range in the electric conductivity called for in the existing specifications.

The tensile strength of hard copper wire is greatly influenced by the actual amount of reduction in section of the wire in the cold drawing operations, and nearly all of the specifications for tensile strength are practical in that they can be met. Obviously, however, the elongation of the wire must decrease with increasing amounts of cold drawing, hence there must be a compromise between the maximum tensile strength and maximum elongation, in order that hard wire may be made and yet produced economically to meet specifications. With respect to requirements, such as the twisting and wrapping tests, it is a fact that the results vary so greatly with the way in which the test is made and with changes in outside influences, that unless all conditions are very carefully defined and observed, the results of the tests themselves are practically valueless.

Another matter which seems worthy of consideration is the variation in practice in specifying the gauge, or size of wire, there being not less than three distinct wire gauges used, as well as some modifications or special interpretations of the values of the gauge numbers. It would greatly simplify matters and make reference definite, if some general agreement could be arrived at whereby the size would be specified in decimal parts of an inch without reference to arbitrary gauge numbers.

To indicate the large range of requirements of existing specifications, we propose to give a few examples. One specification which recently came to our attention requires a tensile strength of not less than 60,000 pounds per square inch; with a minimum elongation of one per cent. in 10 inches and an elastic limit of not less than 36,000 pounds per square inch, the specification appearing to apply to all sizes of hard drawn wire which the company issuing the specification desired to purchase. The size of wire which was called for on a particular inquiry in the case just mentioned, is required in another specification to have a minimum tensile strength of 62,000 pounds per square inch,

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* Paper presented before the American Society for Testing Materials, June 27, 1908.

with a minimum elongation of 1.14 per cent. in 60 inches. Elongations are measured under this specification with stress applied to the wire, while it is to be presumed that under the first specification the elongations are to be measured after the wire has been broken. A third specification requires this same size of wire to have a standard strength of 64,200 pounds per square inch, without any elongation being specified. These three specifications may be considered typical. There is a difference of 7 per cent. in tensile strength actually required of a given diameter of wire, and furthermore, a difference of 500 per cent. in the length upon which the elongation is to be measured. One specification requires the wire to be broken and the elongation then measured between bench marks originally placed upon the wire; while another states the whole elongation which has taken place before fracture occurs, and includes the degree of elasticity remaining in the wire at the time of fracture.

There is another difference to be noted among the three specifications quoted. One of them apparently requires the same tensile strength in hard drawn wire, regardless of its size; and another demands an increasing strength with decreasing diameter, and the increase in strength uniform with decrease in diameter. It is probable that the relation between diameter and tensile strength follows a curve rather than a straight line; and commercial practice in the manufacture of the wire is likely to cause jogs in this curve. If these jogs are not permitted in the curve, it will materially complicate manufacturing conditions.

The elastic limit of the wire is included as a requirement in some specifications and is omitted in others. That this is difficult to locate with any degree of exactness, is obvious. The coiling of the wire sets it in a curve, and leaves it in a state where one side is strained to a greater degree than the other when the wire is pulled straight in the testing machine. There is apparently no jog in the elastic curve corresponding to that at the yield point in steel, hence the elastic limit can not be located, even with fair approximation by the drop of the beam or increase in stretch rate, in the manner customary in steel testing. Recourse must be had to the tedious method of taking extensometer readings, from which the elastic curve may be plotted. Because of the unevenly strained condition of the wire just mentioned, the elastic curve has puzzling inflections, probably caused by small sets taking place on the overstrained side. These make the location of the true elastic limit uncertain. The time consumed in making the test is more than a mill laboratory can usually afford. This, combined with the uncertainties in the results, makes it a debatable question whether it is not better to determine, with fair approximation, the probable ratio of the elastic limit to ultimate strength, for the benefit of the designer, but to omit the location of the elastic limit from specifications, and as a regular inspection test.

A trolley line, or even a telephone line, does not present any difficult problems involving the actual physical strength of the wire of which the line is constructed, because the spans are short by reason of the comparatively small sag that is permitted in such lines. With a long distance transmission line, the case is somewhat different. It frequently happens that the availability of a water-power is to a considerable extent determined by the cost of the transmission line for conveying the power to the desired point of application. The cost of the transmission line is made up, not only of the copper wire entering into it, but also of the poles, the insulators, and the method of suspension. The size, and therefore the cost of the copper wire itself, is to a large extent fixed by electrical considerations. Hence the variable factors in cost may be said to be suspensions, including poles. insulators, etc., and the longer the spans the less will be this cost. The permissible length of span is obviously determined by the physical characteristics of the wire, and the amount of sag which may be tolerated. Hence, the engineer who is designing the transmission line must have accurate knowledge of the physical properties of the wire entering into it.

While hard drawn copper wire and its uses may be of less general interest than some of the problems arising through the use of the more common engineering materials, the extension of electric driving in railroad practice brings this matter under the consideration of many more of our members than might at first be supposed. On this account, and with the hope of interesting the Society and having the subject taken up as has been done with many other materials, these notes have been prepared.

A MODERN SYSTEM OF STREET LIGHTING

By C. A. B. Halvorson

The Worcester Electric Light Company of Worcester, Mass., was one of the first larger electric lighting companies to realize the advantages of the luminous arc. This company, after a year of exhaustive tests on one circuit of 50 lamps operated from a Brush arc generator, replaced its entire lighting system with the new series luminous lamps. The old system, consisting of 800, 9.6 ampere, 48 to 50 volt, open arc lamps, was operated from 8 Brush arc generators, while the luminous lamps are supplied with current from mercury arc rectifiers and constant current transformers. In August, 1907, the new system was started, and since then has been in successful operation.

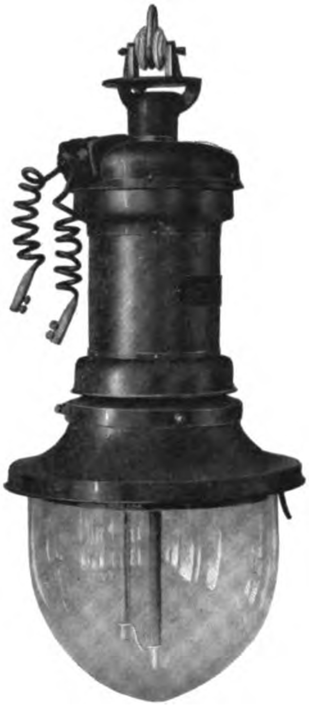

Fig. 1. General Electric Series Luminous Arc Lamp

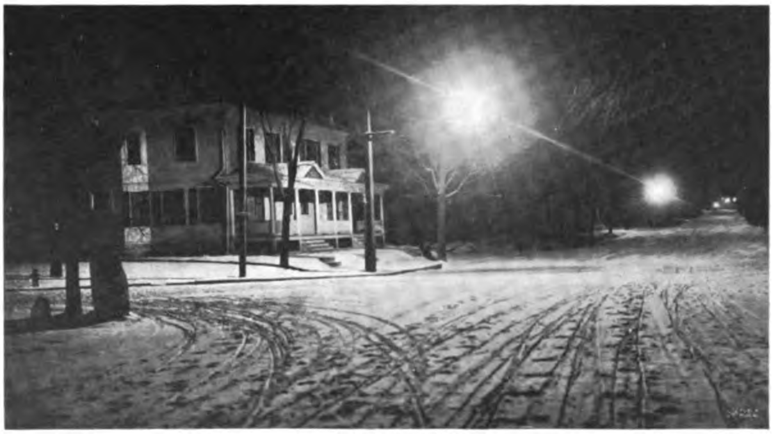

Fig. 2. Street Illumination by Luminous Arc Lamps, Worcester, Mass.

The lamps are of the now well-known Form 3, D.C. series type, shown in Fig. 1. The advantage of this lamp over all other forms of street illuminants is due primarily to the characteristics of the arc, which resembles a flame, and is luminous throughout its entire length of approximately 9/16 in. The light is of a bright white color, and as the arc is maintained in a vertical position, the majority of the light rays are naturally thrown out horizontally. The upper or positive electrode is a cylindrical piece of pure copper, sheathed by a thin iron tube which prevents rapid oxidization, and has a life of approximately 4000 hours. The lower or negative electrode, which determines the quantity and quality of the light, is composed largely of magnetite encased in a sheet-iron tube, and has a life of about 175 hours. The copper electrode has a fixed position with relation to the reflector. As the lower electrode is consumed it is fed upward so that its burning surface is also in a fixed relation to the reflector. With this arrangement the light from the arc is distributed at the most advantageous angle for street lighting; *viz.*, about 10 degrees below the horizontal. As the lamps are hung only 20 to 22 feet from the ground, ample illumination is obtained around the lamp, and further uniformity of illumination is secured by using a globe, sand blasted at the bottom, which combination diffuses light directly under the lamp, eliminating all sharp shadows. Fig. 2 shows a street illuminated by 4-ampere, D.C. series luminous lamps of this installation. It will be seen from the photograph that it is possible to get a uniform distribution between lamps

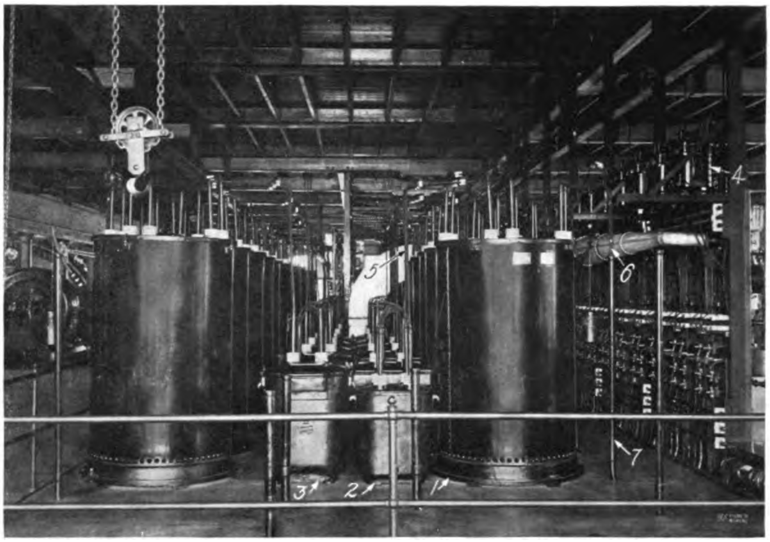

Fig. 3. Constant Current Transformers and Reactances

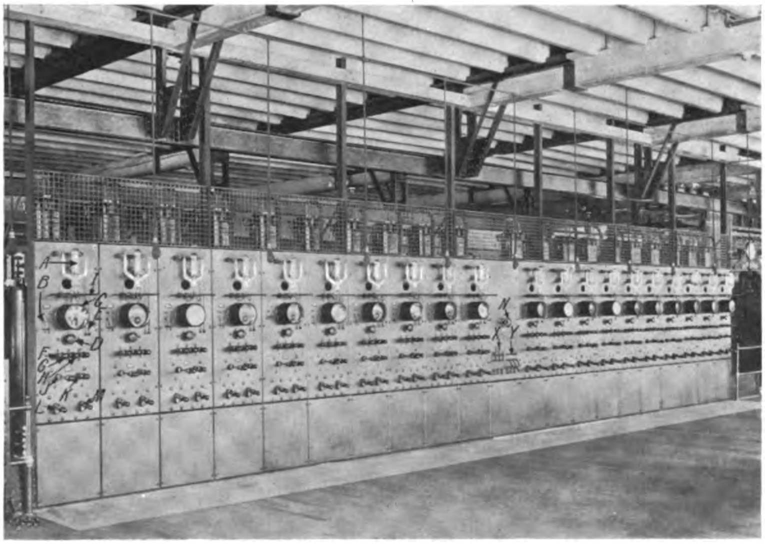

Fig. 4. Switchboard

with a larger spacing than is possible with any other lamp. The distance from the camera to the first lamp was 100 feet; first to second lamp, 350 feet; second to third lamp, 550 feet; and third to fourth lamp, 300 feet. Approximately 98 per cent. of the energy consumed at the lamp terminals is transmitted to the arc; thus it will be seen that the mechanism is remarkably efficient.

The lamps have three methods of suspension; *i. e.*, either of two forms of the Lundin goose-necks may be used, one bolting on the side of the pole, the other fitting over the end; or a trussed mast arm, the lamp being suspended from a truck. With these methods of hanging lamps, there is no means of lowering them into the street, thus eliminating all chances of accident from that source. The poles are fitted with seats for the lamp trimmer, enabling him to work to good advantage. Each lamp is connected to the line through a cutout of the plug type, so located on the pole that when the plug which carries the lamp leads is withdrawn, the lamp is absolutely "dead." Each lamp circuit is carried in an underground conduit system at least two-thirds of its entire length. Where the circuits emerge from the ground, lightning arresters are used, approximately 150 being employed on the entire system.

The station equipment consists of 20 mercury arc rectifier outfits, of 50-light capacity each. At the present time about 830 luminous lamps are installed on 18 circuits, giving an average of about 45 lamps per circuit, and thus allowing the addition of more lamps on each circuit as required. As shown in Fig. 3, each outfit consists of a rectifier tube, Type M.S., Form B, 2200-volt primary, 4500 rectified volts; oil-cooled constant current transformer (1); two oil-cooled reactances, one in each secondary line connected to the rectifier tube anodes, both being included in one case (2); and an oil-cooled reactance in the secondary line leading from the tube cathode through the lamps (3). There is also a 110-volt, 100-watt transformer, of ratio 1:1, used to excite each tube, which is shown over the top and back of switchboard (4). The primaries of the exciting transformers are controlled separately by a switch on each panel, the secondaries being connected directly to the starting anodes and cathode of each tube.

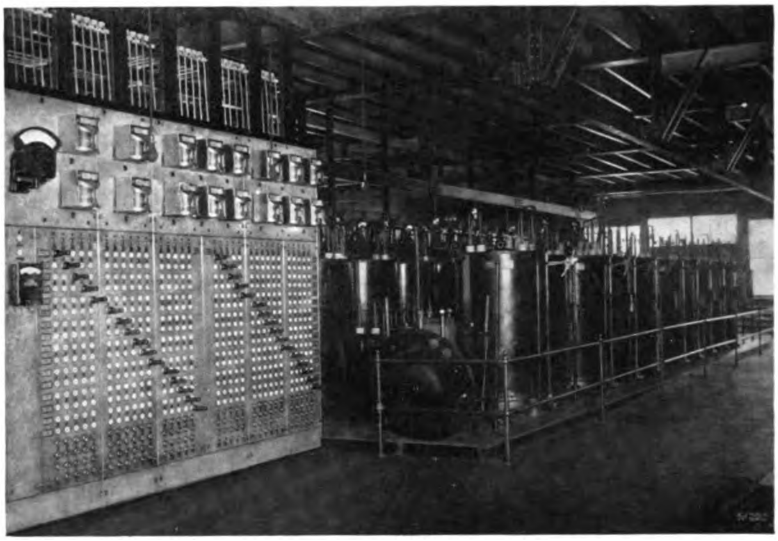

Fig. 5. Arc Circuit Transfer Board and Transformers

The 2300-volt, three-phase bus bars from which these outfits are excited run across the back of the rectifier switchboard for the full length of the board, each outfit being tapped from alternate phases. This method of wiring nearly balances the system. With 18 sets running the system is exactly balanced. The bus bars are connected directly to the main 2300-volt bus bars through a three-phase, motor-controlled oil switch, the main bus bars being excited from three-phase, 2300-volt, 60-cycle generators, thus doing away with any intermediate transforming apparatus.

In connection with these outfits we have two 7½ kw., 2300-volt primary, 110-volt secondary transformers to supply 110-volt current for the exciting transformers and for the motors used in connection with the tube-cooling device. The motors are controlled from switches shown at X and Y, Fig. 4.

The cooling equipment for the mercury arc rectifier tubes consists of two motors, I-8-7½ h.p., 900 r.p.m., Form K, 110-volt, mounted on a common base with, and direct connected to two B.F. Sturtevant Company's special 60 in. steel plate exhaust fans. This equipment is in duplicate, with a common housing. Each fan is capable of delivering 8000 cu. feet of air per minute, while the piping is designed to deliver 400 cu. feet per minute to each tube. The inlet piping to these fans is so designed that it is possible, by means of a suitable damper, to take air from the outside, or from the basement where the fans are, whichever arrangement is necessary to keep the air at an even temperature. This blast is controlled between panels and fans by one main damper (N, Fig. 4) which closes the outlet from the fan which is not running. Each panel has a separate damper (D, Fig. 4), allowing individual control.

In the wiring of this installation a very radical departure was made from the wiring of other similar installations in that all wires from the transformers to the panel boards are carried in iron conduits (7, Fig. 3) imbedded in the concrete floor upon which the transformers stand. As the three secondary wires (5, Fig. 3) from each transformer are placed in one conduit, and likewise, the primary wires (6, Fig. 3) in another, a specially insulated wire is necessary. The wire used is insulated with $\frac{7}{32}$ in. thick, 35 per cent. pure rubber, to withstand a 45000-volt test. The insulation is covered with a heavy webbing for protection. The wires in each conduit are grouped together in a casing made of the same insulating material as that used on the individual wires, thus giving the same insulation between the wires and conduit as between wires. This method of wiring is more compact, takes up much less space, and has proved very satisfactory in operation. The lamp circuits are carried out from the rectifier panels to a distribution plug board (Fig. 5), thus allowing any circuit to be plugged on any panel. The circuits are not metered separately, but one 2300-volt, three-phase meter records all power used by the entire system.

It will be noted that there is space in this installation for four more outfits of the same description. The total floor space occupied, including switchboard, transformers, and space for four extra sets, is 54 ft. 6 ins. by 17 ft. 10 ins. Another feature of the installation is the permanent crane which facilitates the handling of the transformers, etc. This is clearly shown in Figs. 3 and 5.

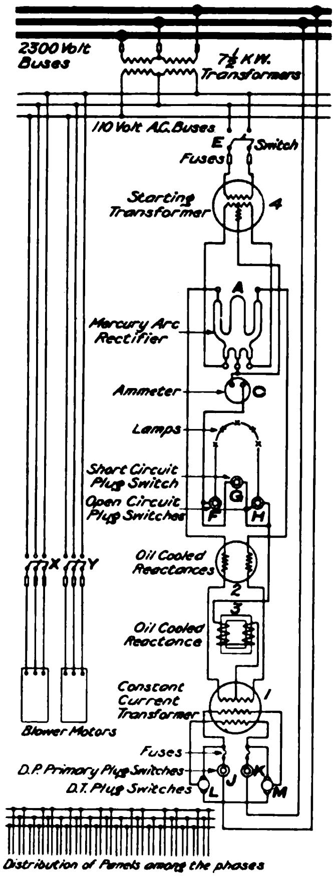

Fig. 6. Switchboard Wiring for One Mercury Arc Rectifier Outfit

Each of the 20 panels are fitted, as shown in Fig. 4, with a mercury arc rectifier tube (A), tube shaking device (E), D.C. ammeter (C), air controlling damper (D), and switch (B) for controlling primary of exciting transformer. The three upper plugs (F, G, H) are the secondary or load plugs, while the two outside plugs (F, H) connect the tube to the load. The middle plug (G) is for short circuiting the load. The four lower plugs (J, K, L, M) control the primary of the constant current transformer, and serve for making multiple connection of coils for running under load on 2200 volts, or for connecting the coils in series for drying out the tube, with the load short circuited.

Fig. 6 shows the switchboard wiring for a single outfit, and the lettering corresponds to the lettering of Fig. 4, which has been described.

Data is given in the accompanying table, showing a comparison of the old and the new system.

Accurate data on rectifier life is not at hand, but the Worcester Company has obtained an average life considerably in excess of 500 hours.

	9.6 AMP., D.C.C. OPEN ARC		**4 AMP., D.C.C. LUMINOUS ARC**	
Efficiency	Watts per lamp at engine crank shaft 657.5 Efficiency = 67%	Watts per lamp at arc 440.0	Watts per lamp at engine crank shaft 357.0 Efficiency = 87%	Watts per lamp at arc 311.0
Life with a Ten Hour Day	16 hours per trim, or 8 hours per set of carbons. This lamp requires one new set of carbon one day and two new sets the next. Carbons waste 1.5″ per hour.		175 to 200 hours. Trim every 20 days. Upper electrode 4000 hours, or practically non-consuming. Lower electrode consumes .033″ per hour.	
Trimmers	Ten trimmers, trimming 80 lamps every day.		One trimmer, trimming 50 lamps every day.	
Angle of Greatest Intensity	Angle of greatest intensity = 45 deg. below horizontal, which causes a dark band around lamp making uniform distribution between lamps impossible.		Angle of greatest intensity = 10 deg. below horizontal. Light is diffused over greater area and dark space between lamp is practically eliminated.	
***Luminometer Readings**	247 feet from lamp.		330 feet from lamp.	
Prices of Carbons and Electrodes	$.007 per carbon—Use 6 carbons. One day = $.022.		$.05 per electrode—20 days; or $.0025 per day.	

*** The luminometer is an instrument devised to show the lighting distance at which a predetermined intensity can be observed.**

THE RELATIONS BETWEEN COMMERCIAL AND ELECTRICAL ENGINEERS*

By Chas. B. Burleigh

Dictionaries and other reference books do not clearly define either of the words "engineer" or "engineering," in the sense in which they are used to-day.

Consider first the word "engineer." Formerly this word applied to the man who operated an engine, and the necessity for a title for this person presents the reason for the coinage of the word. It was, however, entirely too broad for this limited application, and it soon began to reach over on all sides, until to-day it is probably the broadest title in the English language, and may be justly appropriated by any person accomplishing any result which requires a combination of thought, action, and skill.

The title is therefore subject to innumerable divisions, but for the present we are interested in, and will take note of, but two of its many applications; namely, the Electrical Engineer and the Commercial Engineer.

In equitably defining each of these, we are again thrown upon our own resources, as we are again met by the many subdivisions, covering the designing, constructing, erecting and operating engineers; and while each must possess many characteristics common to all, so also must each possess additional characteristics which are peculiarly adapted to that particular branch or department of electrical engineering in which he is to achieve his success. We may, however, broadly define the electrical engineer as one who designs, constructs, erects or operates electrical apparatus. The commercial engineer, is even more difficult to equitably define, but by the introduction of the word "electrical" we simplify the problem.

I appreciate the fact that some might feel like defining this production as an electrical engineer who was spoiled in the making, discarded by its makers, and by them thrown into the commercial scrap-heap, where, for some unknown reason, it continued to thrive until it blossomed into a commercial engineer having no other aim in life than that of spending its time in devising means whereby it could harass and worry its former friend and associate, the electrical engineer.

But you realize as well as I that this is not so; that the commercial electrical engineer is one who should possess all, and must possess most, of the characteristics of the electrical engineer, and in addition, the commercial instinct necessary to discover the application, devise the method, and secure the means to accomplish the desired result in such a manner as will produce an equitable financial return for the money invested. Notwithstanding this fact, I readily admit that the electrical engineer is, and must necessarily be, the more refined production; for it is only by perfecting himself in all the minor details of his calling that he is enabled to establish and maintain his standing.

The vast army of commercial engineers is largely made up of electrical engineers who have, from time to time, found it undesirable, from one cause or another, to attempt to maintain their standing.

The comparatively recent advent of the electrical industry and its phenomenal growth are in a measure largely responsible for this, as was also the mistaken impression (which is still prevalent, and the correcting of which is largely the object of this writing), that the commercial engineer's life is one much to be desired—that he goes and comes when and where his fancy dictates, is well groomed, care free, and well paid. In fact, to the uninitiated, his career appears to be one sweet song from year to year, with little other object in life than to hunt up problems with which to make the life of the electrical engineer as unbearable as possible, and, at the same time, impress upon the minds of an admiring public what a wonderful engineer he himself is.

In order that one may be enabled to more fully comprehend the attractions presented by the field of commercial engineering in the early days of the art, it is necessary to step back some twenty-five years and examine the electrical engineer of that period. He had no schooling in electricity, for it was not obtainable. The more fortunate were well grounded in mathematics, physics and mechanics; and these were the only available assets that could be acquired, which in any way qualified the men for their chosen career. If they were also equipped by nature with a fund of common sense, resourcefulness, and determination, these, in conjunction with their education, represented the qualifications best fitting them for the new field. Many of those entering the field were better equipped by nature than by education, and *vice versa*.

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* Extracts from a talk on this subject given by Charles B. Burleigh, before the G. E. Engineering Society.

Few of the electrical engineers of to-day can appreciate the handicap under which, twenty-five years ago, he that would be an electrical engineer started; and to present this more forcibly I will relate the early record of a commercial engineer who is still in the employ of the General Electric Company.

This young man was a native of one of Boston's suburbs; had graduated from the grammar school and entered the high school, when the death of his father obliged him to seek employment, which he found with the American Bell Telephone Company in 1879. For some three years his experience was quite varied, covering all lines of inside and outside construction work, as applied to telephone and telegraph applications, as well as burglar alarm, fire alarm, electric gas lighting, annunciator and electric bell work; and, in 1882, we find him, at the age of twenty, in Minneapolis, Minn., in the employ of the Erie Telephone Company. He had already discovered the inadequacy of his engineering education, and had cultivated the habit of employing his spare time in self-education. A contract was closed by a Western concern to install 500 incandescent lamps in one of the Washburn Flour Mills, and great difficulty was experienced in procuring a man capable of taking charge of the installation.

Our young friend, learning of the situation, called on the manager of the contracting concern and offered his services, and was engaged. He had at this time never seen an incandescent lamp, but had read of them in the technical press. He knew the difference between series and multiple wiring, and was considered an expert wireman, but knew little of voltage, current or resistance. Safety devices, such as fuses or circuit breakers, were unknown at the period, and he wired the mill with cotton covered, paraffine coated wire without safety devices. Flour mills operate day and night, and the room designed for the generator was used by him as his stock room, and was kept locked. When the generator, which was a 50-volt, 600-ampere machine, arrived, it was disassembled, and it was the custom of this young man to spend his evenings in studying its assembly. He was familiar with the characteristics of the magneto bell, and knew enough to realize that the principal difference between this generator and the magneto was that the magnetism of the former was maintained by the use of electromagnets, while that of the latter was maintained by the use of permanent magnets. The commutator was a part, of which his knowledge was extremely vague. However, with his limited knowledge he succeeded in assembling and connecting the generator. As previously stated, his learning had not reached a point where he was enabled to realize the effect of voltage. He had gained the impression that electric light machines were dangerous, and really felt that when he started the machine, the chances were about even of his surviving the ordeal. Finally the crucial moment arrived. He procured a large sheet of wrapping paper, wrote his name and home address on it, adding the words, "send me there," locked the door, and at midnight on the 3d of July, 1882, closed the main switch.

The commutator sparked badly, but the machine generated, and he still lived. Common sense told him that something was wrong, and he experimented every night until he finally discovered that the set of the brushes and the speed of the machine materially affected results.

This experience is unquestionably laughable in view of to-day's knowledge, but I assure you, was a serious matter then.

The experience of this young man is but one of many, and is it to be wondered at that as our colleges and technical schools began turning out a liberal supply of electrically trained engineers; that the engineers equipped only by nature and their own exertions should gradually drift toward that branch of the business where the competition was bound to be less severe, and where experience was the only available teacher, thus giving them as good an opportunity for keeping abreast of the times as could be found available for others?

This brings us to a point to which I would like to call attention very forcibly. None of us are perfectly contented with our lot. The ambition of many an electrical engineer is to enter the commercial field; seeing therein, as previously stated, escape from routine work, working hours of his own selection, entertainment galore, sight-seeing without stint, fabulous salaries and easy work; and failing to appreciate the facilities he now has for keeping abreast of the latest electrical engineering developments, and the exceptional advantages he has for excelling in his line.

He also loses sight of the fact that he must put himself in competition with the years of commercial training of his new associates, and that he must possess abnormal qualifications in this line to learn the game in a short enough period to prevent his electrical knowledge from becoming more or less obsolete while so doing; and in trying to keep his electrical knowledge up to date, he tends to paw the air (so to speak) to keep in as close touch with engineering developments as his early training has taught him is desirable.

His commercial competitor, meantime, is so familar with the trade conditions, and so accustomed, from years of training, to select just the engineering features necessary to keep in touch with, that he is in a position to select his study, and will therefore progress in this line fully as fast, if not faster, than his rival; therefore, the aspirant for commercial success enters no smooth road in making the change.

The commercial engineer looks with equally envious eyes at the electrical engineer, thoroughly appreciating his engineering advantages and his home life.

Let us analyze some of the apparent comforts of the commercial engineer. His time, day or night, is never his own. His success is wholly dependent on the volume of business he can do. This is of no interest to the people from whom he must procure it. He must, therefore, cater wholly to the wishes of his customers to the sacrifice of his own desires, going when or where their fancies dictate, regardless of social or family alliances.

The merry times and entertaining features which appear so attractive to the uninitiated are the bugbear of the commercial man, for they are exceedingly wearing and have sometimes wrecked the strongest constitutions in a few years. One of the hardest lessons the commercial engineer has to learn is to dodge entertainment and entertaining without offending the trade, and if he does not succeed in thoroughly mastering this phase of the situation, he cannot possibly stand the pace. The sight-seeing and traveling which appears so attractive is plentifully interspersed with poor accommodations, anything he can get to eat, and in many cases, stand up or run and grab meals.

Another reason why the electrical engineer has no reason to envy the commercial engineer is that, let him once forsake his calling and join the commercial force, and he can never hope to return. If he is not a success as a commercial proposition, the training he has received while finding it out has absolutely unfitted him for an electrical engineer; and again, during the time he has been discovering himself, his more sensible associates have left him in the race, as he has become obsolete as an engineer.

We now arrive at the most alluring feature in connection with commercial engineering as compared with manufacturing engineering, and that is, the supposedly enormous salaries paid the commercial engineer.

It may be surprising to learn that the average salary paid the commercial electrical engineer is 30 per cent. less than the average salary paid a wholesale shoe salesman, and from 40 to 45 per cent. less than that of the average wholesale ready-made clothing salesman; neither of whose occupations require any technical knowledge. So if one is dissatisfied with his lot and feels that he prefers the commercial man's lot, let him look to a line of wholesale goods and throw away all the time and money he has put into his education.

Neither the manufacturing electrical engineers' or the commercial electrical engineers' lot is without its drawbacks, and each should settle down, determined to excel in his own particular branch of the business.

The easiest way for a man to better his own condition is to contribute more to the success of his employers. In order to give this phase of the subject the consideration it deserves, we must pursue a circuitous path, analyzing first the reason for the engineer's existence.

The first item for consideration in this connection is the man who wishes to purchase electrical apparatus. He does not become possessed of this wish of his own free will, and we might start back of him, with the conditions which are father to his wish; but I feel that the customer should be the starting point, and we must bear in mind that local conditions govern his requirements almost wholly. He goes carefully over his local conditions himself, possibly employs expert assistance and finally determines just what he has to purchase to meet these conditions, and also determines just when it is necessary for him to have them.

He sends to the manufacturers and informs them of his wants. The demand is created, and that is the starting point of business. If there were but one manufacturer who could give him just what he wanted, just when he wanted it, no salesman would be required, and the manufacturer could simply name him a price regardless of cost, and be sure of securing the business. But in most cases, few concerns can give the customer just what he wants, and even fewer can give it to him just when he wants it. However, every manufacturer who produces goods anywhere near his requirements sends a representative to interview him. If one of these manufacturers can meet the conditions exactly and none of the others can, he is pretty sure of the business. If several concerns can exactly meet the conditions, the one who can do so at the lowest cost is pretty sure of the business.

These three features, *variety*, *price* and *delivery*, are capable of many different combinations, but they all demonstrate one fundamental principle: that the concern that can meet the greatest variety of conditions, in the shortest time and at the lowest cost, will be the most prosperous concern.

The customer, therefore, is the one on whom the concern is dependent, and he is also the one who determines the character of the goods, the time of delivery, and the price.

On receipt of information that a purchase is contemplated, the manufacturer sends a man to interview the prospective purchaser. If this concern were the only one that could meet the conditions, a letter would do; but as this is not the case, it is necessary to send a man.

All concerns in our line of business, realizing that different conditions must be met by different classes of apparatus, find it necessary that this man be an electrical engineer; and realizing also that the commercial conditions involved must be carefully considered in order that the equipments supplied may best meet them, they find it necessary that the electrical engineer must also be a commercial electrical engineer.

On the loyalty, honesty, tact, resourcefulness, knowledge, judgment and energy of this man, is dependent the information as regards the requirements of the customer which the concern receives. A book could be well written on just what this man should be, but I will endeavor to confine myself to the characteristics he should possess affecting the manufacturing.

He should thoroughly appreciate the fact that special apparatus of any nature not only affects manufacturing costs, but seriously interferes with factory routine to the extent of seriously handicapping deliveries.

It may therefore be put down that the poorer the salesman the more special apparatus he will call for. Most anybody can sell a man what he wants, but the man is a salesman when he can sell a man what he thinks he doesn't want.

You may make up your mind that whenever you get an order for something special from a high-grade salesman that he has exhausted every argument, and found it absolutely necessary, in order to secure the business, to meet the requirements of the purchaser.

The same arguments are true to a certain extent in connection with deliveries, although this item does not present quite as fair a basis on which to judge of a salesman's ability; for the reason that in the majority of cases time is money to the purchaser, and the time intervening between the necessity becoming apparent, and operation of the apparatus, represents a given amount on idle investment, and it is often better judgment to purchase inferior apparatus at higher prices than lose a large amount in interest on the investment, dependent on the apparatus. For this reason also delivery is in many cases the most important item to the purchaser.

I will not discuss the commercial engineer further, but will put him down as the second step, as he now represents the customer in his dealings with the concern, since it is from him the concern learns what it is necessary to furnish, and when.

We now come to the electrical engineer. On him devolves the design of the apparatus which shall meet the customer's conditions. And here we come to the heart of the whole situation.

As far as the manufacturer is concerned we are dealing with the two extremes, the Alpha and the Omega of the whole situation—the commercial electrical engineer who presents the requirements, and the designing electrical engineer who meets the requirements; and the closest connection they have in business is through the many steps before enumerated.

Do you think it productive of the best results? Let us consider for a moment two questions.

How profitable a business do you suppose a concern would do which attempted to manufacture every article which a salesman could take an order for? On the other hand, how profitable a business do you suppose a concern would do which attempted to market every article the engineer could devise?

I think you will agree with me that it would result in a race as to which concern would die first. What then should produce the best results?

Why not bring these two extremes together in the closest possible contact, promoting the discussion of pertinent matters, to the extent that each would have a higher appreciation of the difficulties to be met by the other, with material benefit to the concern. On their advancement, as before stated, is dependent our own success.

How many of the commercial engineers, do you suppose, have any appreciation of the amount of work involved, or the expense entailed to their employers, by requiring that a guarantee be given on some particular generator, one per cent. better than would be safe to expect from standard production?

On the other hand, how many designing engineers do you suppose have any idea of the amount of work necessary, or the expense entailed in selling the old distributor boxes for operating incandescent lamps from the series arc circuit, or the so-called compensator system of the vintage of 1889, or the monocyclic system of more recent date?

Recommendations from the commercial engineer embodying the first or from the designing engineer embodying the latter, would result in expense to their employers, for which they would receive little, if any, return.

This brings us to a phase of the situation which I approach with a great deal of hesitancy, as I fully realize that the position which I shall take will be such as may lead you to feel that I wish to assign to the commercial engineer, prerogatives to which conditions would not entitle him; but I am prepared to sustain the position that I take in stating that the commercial electrical engineer should be one of the most important factors in determining the nature of the product of the electrical manufacturer.

The next factor, and one of almost if not quite, equal importance, is the designing engineer; but under no circumstances should the second overshadow the first, for if he does, the result may be that the product will not meet the commercial conditions to the very best advantage, and if it does not, the object of their design has not been fully gained.

The third factor is one in almost equal importance to the other two; that is, the constructing engineer, for on his skill is dependent the cost of manufacture, as well as the time of delivery.

Let us consider these three factors as delta connected, just as they should be.

It is obvious that we can not afford to locate the constructing engineer at the top of the triangle; which, then, of the other two should occupy this exalted position? Suppose we assign it to the designing engineer; he may design a piece of apparatus which would be absolutely unsuited for any commercial application, or which would be so expensive to produce as to make its commercial adoption prohibitive.

Let us try the commercial engineer at the top of the triangle. He meets the commercial requirements, or, in other words, the source of revenue; and if he is the man he should be, he sees what should produce results.

But you say he does not know enough to appreciate the fact that there is any possibility of meeting certain results, and I will admit this to be the case, and present this fact as one of the strong arguments in favor of this closed delta connection; but if ideal conditions exist, consultation with the designing engineer will soon inform him as to the possibilities, and the designer of the demand, and consultation with the constructing engineer will enable them to jointly arrive at a profitable solution of the problem.

MOTOR DRIVE IN A SOAP FACTORY

The Pearline Works of James Pyle & Son is the largest factory in the world devoted to the manufacture of soap powder.

It is located on the New Jersey side of the Hudson River at the foot of the Palisades, opposite 98th Street, New York. Here twelve acres of land were purchased, and upon this four large buildings were erected, each a separate unit in itself, but connected with the others by means of covered passageways terminating in fireproof doors. All the buildings are of brick, and those devoted to manufacture are strictly fireproof in every respect. The plant is completely equipped with the latest forms of automatic machinery, driven throughout by General Electric Form K induction motors; the power, which is furnished at 60 cycles, 220 volts, being generated in the Company's own power plant, which also supplies the current for lighting, and the steam for heating the kettles and for warming the buildings.

Following the order in which the Pearline is manufactured, the first motors to be considered are the two 15 h.p. machines (I-10-15-720-K) located in the basement of the grease house and used to drive the Taber pumps for pumping oils and grease to the weighing tank. These pumps have a capacity of 1000 lbs. per hour; the motors drawing 26 amperes.

All material used in the manufacture of Pearline is accurately weighed and then passes to the kettles, where the grease (so-called) and alkali are boiled to make the Pearline, the kettles being heated by steam coils fed from the power-house.

Ascending to the manufacturing room, we find a 35 h.p. motor that is used to stir one of these huge caldrons, the capacity of which is 120,000 lbs. of Pearline per day. When in operation this motor draws a current of 75 amperes. This room is equipped with a second, and very much larger kettle, together with a 50 h.p. variable speed motor for driving it; but at the time of the writer's visit, this machine was temporarily shut down.

The next point of interest is the Pearline slab storage room, into which the Pearline comes in the shape of immense blocks of soap, and where it is cut into slabs preparatory to grinding. Here are located two slabbing machines with a capacity of 70,000 pounds per hour, run by one 5 h.p. motor drawing 12 amperes.

From the slabbing machines the Pearline passes to the cold storage room where it is stored until in proper condition for grinding. A low temperature is maintained in this room by means of the ammonia refrigeration process and brine circulation, the air being continually kept in motion by General Electric sixteen-inch desk fans.

Passing now to the grinding department, we come first to a 35 h.p. motor (rated I-8-35-900-K) running the chopper, which machine is used to break up slabs of Pearline into the proper size to be fed to the cage mill. This motor also runs this cage mill, and when in operation draws 65 amperes. Here is also located a 50 h.p. motor (rated I-8-50-900-K) drawing 120 amperes, and driving six grinders that produce 16,000 pounds of ground Pearline per hour; the Pearline being fed to the grinders in slab form.

From the Grinding Department, the Pearline is raised by a bucket elevator, driven by a 5 h.p. motor which is installed in a small enclosure on the roof of the building. It is then delivered to a flight conveyor which distributes it to the various packing machines, the conveyor being operated by a 7½ h.p. machine located in the Pearline storage room. One hundred and fifty thousand pounds of Pearline a day is carried up and distributed to the packing machines in this manner.

The tailings from the cage mill are also raised in a bucket conveyor driven by a 7½ h.p. motor, and another 7½ h.p. motor, drawing 20 amperes, is installed in the Pearline storage room for the operation of a revolving sieve 12 ft. long by 4 ft. in diameter, used to sift the alkali. This motor also drives a 9-inch worm conveyor which distributes the stored Pearline. Nevertheless, this current is rather in excess of what might be expected from the work performed; this is due, however, to the fact that under ordinary climatic conditions, the Pearline is apt to clog the chute and obstruct the operation of the sieve.

In addition to the motors driving the machines directly used to manufacture or handle the Pearline, a number of others are employed for other purposes incidental to this industry. In the packing room, for example, a 20 h.p. motor is installed to drive the various machines used in packing. These are the carton making machines, the bottom folding, the weighing, and the top sealing machines. Here also is located a motor that operates the nailing machines and conveyors for the wooden boxes in which the packed cartons of Pearline are shipped.

Installed in the Pearline storage room are the 7½ h.p. motor, running the worm conveyor that feeds the alkali to the kettle, and the 10 h.p. machine that operates the elevator and the worm conveyor, used to carry the alkali.

In visiting the plant one is immediately struck by the remarkable ability of these motors to operate successfully under adverse conditions. In a number of the rooms, notably those devoted to the grinding and the Pearline storage, the air is full of Pearline dust—sometimes so dense as to completely obscure the workmen from view. In several cases the motors have been housed under frames upon which cheese cloth has been stretched, thus protecting the machines to a considerable extent, although not perfectly, as the fine Pearline dust penetrates the cloth. In a number of instances, however, it is impracticable to thus house the motors, and in these cases the machines are completely at the mercy of the fine Pearline and the alkali dust, which coat the machines and permeate every crevice, filling the interstices between the finger blocks and the field flange, and stopping these vent ducts so that ventilation through them is impossible. The dust is more or less deliquescent, and upon absorbing moisture, forms a coating that is peculiarly difficult of removal. The action of the alkali is very noticeable upon the name plates, which become so corroded as to make it well nigh impossible to read the ratings. Notwithstanding all this, the motors run continuously and satisfactorily.

MINE HAULAGE

By C. W. Larson

Electric haulage has long been recognized as the most successful system for transporting the mine products from the interior of a mine to the place or places where deliveries are made, either to steam roads for further transportation, or to mills; and the objection to electricity in mines, which was so much heard of a few years ago, is a thing of the past. The conditions, however, are greatly changed and in many instances it becomes quite a difficult problem to design machines of the required capacity. This is due to the fact that the distances of hauls are getting longer and the output greater year by year; while at the same time, in most mines, the track is narrow gage, varying from 18 to 36 inches.

Ten years ago, when considering a haulage installation, the heating of motors was of less importance than it is at present; for the hauls being short and infrequent, the motors were of ample size as long as they produced the torque required for the necessary traction. At present the distances in many mines run up to 6 or 7 miles; consequently the motors which were good for a run of one or two miles are too small for this six or seven mile service unless the load is reduced in proportion, and this is out of the question; for, on the contrary, the longer the hauls, the bigger the trains. This difference in the situation is not readily appreciated, and sometimes gives rise to the remark that a certain motor or motors used to be good but have of late given all kinds

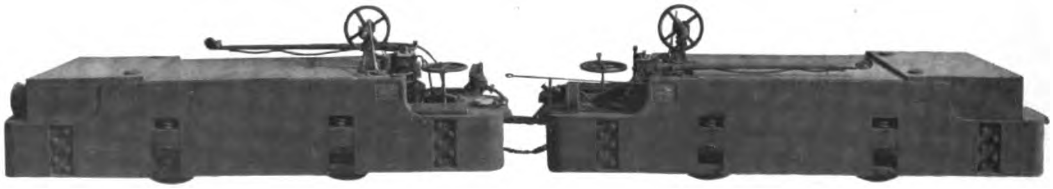


Fig. 1. Two 20-Ton Locomotives Coupled in Tandem

of trouble. It will readily be understood that it is not at all the fault of the motors except in that they are too small for the duty.

Take, for example, the General Electric thirteen ton locomotive: This machine equipped with two 45 h.p. motors has operated successfully for years, but due to the increased distances of haulage, the motors have become too small, and in order to handle the full tractive load produced by the thirteen-ton weight on four drivers, it requires, in a good many places, motors of 75 or 100 h.p. capacity. Motors of this capacity are practically the limit for 36 inch gage, and the only way to further increase the hauling capacity is either to run two or more locomotives in tandem, or to build three or four motor locomotives.

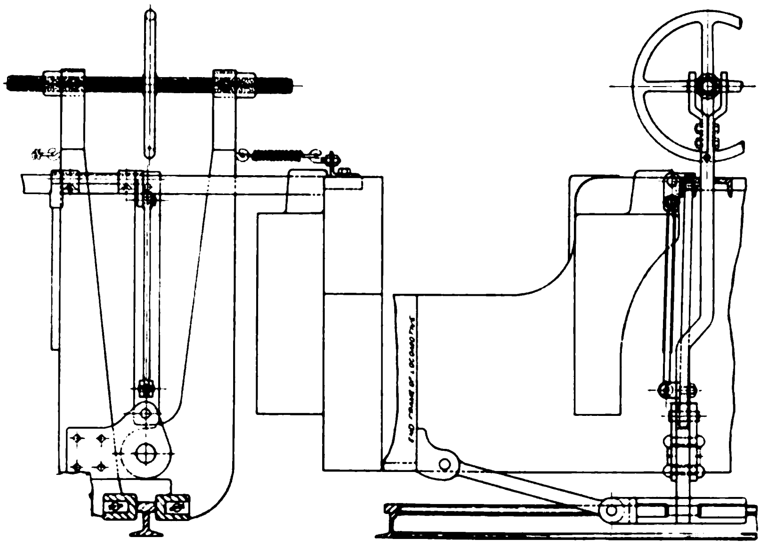


Fig. 2. Diagram Showing Special Brake

Heretofore it has been customary to select locomotives from the draw-bar pull rating; this practice will not hold good for present conditions, and in order to select the proper equipments, complete data on duty cycle, grades, loads, distances, etc., must be worked out in much the same way as in regular railway work, only to a greater extent, as further conditions must also be considered.

In the design of mining locomotives peculiar and widely varying conditions have to be met. The gages of mine tracks vary from 17 inches up to 56½ inches, and the clearances along sides and roofs are in no two mines the same. This imposes limitations as regards over-all dimensions that are sometimes very difficult to meet. A matter of a few inches in over-all dimensions sometimes becomes a determining factor in the sale of a locomotive. As an illustration of this, a case came up some months ago where a copper company wished to double track their mine, and claimed that if the width of the General Electric standard ten-ton locomotive could not be reduced, they would be forced to spend some $50,000 in enlarging their tunnel. This requirement was met by designing a special side frame that was undercut to allow clearance for the wheels. Recent work has been characterized by a number of new designs that have been brought out to meet special conditions. A short description of some of these may prove of interest.

During last February, three LM-207-B-1, 36 in. gage, 250 volt, 20-ton locomotives were completed. Two of these locomotives are arranged to couple together and operate in tandem, as shown in Fig. 1, the motors, brakes and sanding apparatus being controlled from the operating end of the forward locomotive. This tandem set has a total weight of 40 tons, all of which is on the drivers, and a total motor capacity of 400 h.p., each locomotive being equipped with two GE-71, 1-turn, 250-volt, 100 h.p. motors. The speed, at the rated draw-bar pull of 15,000 lbs., is 8.2 miles per hour. Steel tired wheels are used, and the set is capable of developing a tractive effort of between 20,000 and 24,000 lbs. This is probably the heaviest locomotive equipment of the mine type ever built.

Type M multiple unit control is used, contactors, reverser, rheostats, etc., being mounted at the front end of locomotive between side frames and protected by sheet-iron cover, which, when removed, renders them readily accessible. This is the first application of this type of control to mining locomotive work.

brakes. The mechanism and operation of this grip brake is clearly shown in Fig. 2. The jaws are arranged to press shoes against a third rail, which is laid in the center of track and is the same size as the regular rails. This brake is powerful enough to stop a train within a distance of 100 ft. on an 8 per cent. grade, the train weighing 100 tons (exclusive of locomotive), and running at a speed of eight miles an hour.

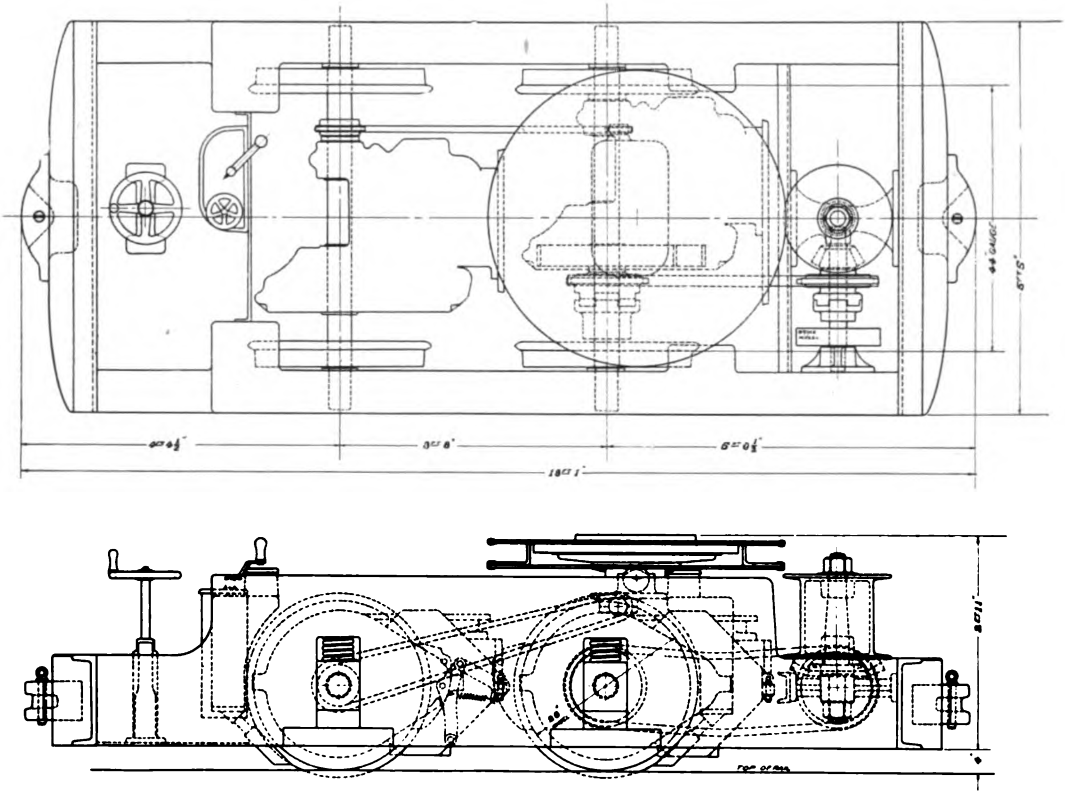


Fig. 3. Diagram Showing Arrangement for Driving Hoist Drum by Forward Motor

These locomotives were built for the Westport Stockton Coal Company of New Zealand, and will be used in hauling coal trains from their mines back in the hills down to the seacoast, a distance of some seven miles. The grades over the line are very heavy, in some places running as high as 12 per cent., the average grade being about 7 per cent. The grade is with the load throughout the entire line, and in order to insure being able to control the loaded trains, a special grip brake was furnished in addition to the usual wheel brakes.

Frequent inquiries have been received of late regarding locomotives equipped with hoist drums. In portions of many coal mines, particularly in the Southern soft coal field. the coal vein dips very sharply from the horizontal, and consequently the tracks leading from entries to the working face have steep grades, sometimes up to 30 per cent. and even greater. The only thing that can be used on a track of this kind is rope haulage. A hoist drum therefore proves a very valuable addition, as a locomotive so equipped can then be blocked on the track in the entries, and, by means of the hoist cable, cars can be hauled up or lowered on the steep grades to and from the working face of the rooms. The General Electric Co. has already built locomotives of this character, each with a hoist drum mounted on top and driven by a separate motor. Recently, however, a new design has been developed which uses the forward motor of the locomotive for driving the drum. This arrangement is shown in Fig. 3. A sprocket wheel is mounted on a sleeve, which has a loose fit on the forward axle. The axle gear and one section of clutch are also mounted on this sleeve, the other half of clutch being keyed to the axle and having a sliding fit on same. Both the clutch on the axle, and the clutch on the shaft which drives the hoist drum are connected to a shifting lever, which extends back to the operating end. With clutch on axle thrown out, the forward motor drives gear and sprocket only and has no tendency to turn axle, but the same movement that threw this clutch out, throws in the clutch on the drum shaft, and hoist is thus positively driven through sprocket chain by forward motor. When hoist drum is not in use, a reverse movement of the shifting lever disengages its clutch and at the same time throws in axle clutch, thus connecting the motor positively to the axle. By means of a double throw switch, the rear motor is cut out of circuit, and the regular locomotive controller and rheostats used for the hoisting work.

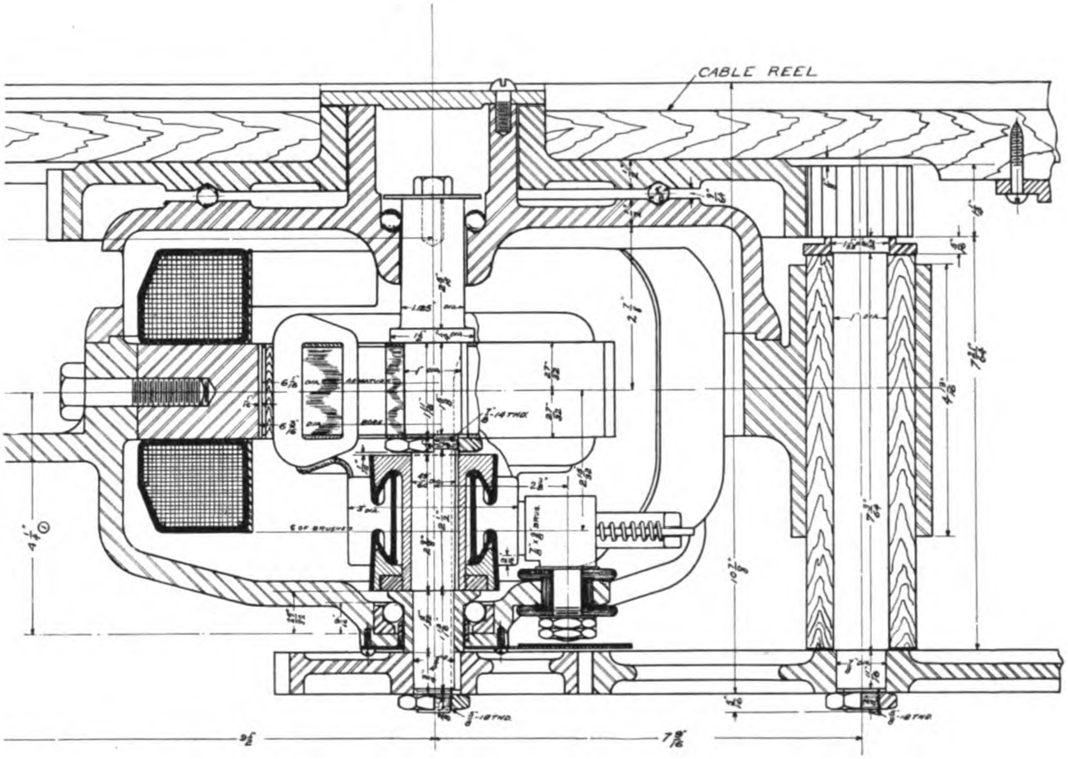


Fig. 4. Section of Motor-Driven Cable Reel

When a locomotive is equipped with cable reel in addition to the hoist drum, there is hardly any proposition in the haulage line that it cannot meet. In view of the large number of inquiries received from mine operators, it appears that there will be a considerable demand for this type of apparatus.

Fig. 4 shows a new scheme of cable reel operation that is now being tried out. The present standard reel is driven from one of the locomotive axles by means of a sprocket chain and system of gearing and friction discs; this apparatus, while highly successful, is necessarily rather complicated and involves the use of a large number of parts. In the new methods this axle-drive is eliminated, the reel being driven through double reduction gearing by a small vertical series motor which rates about ½ h.p. This motor is connected permanently across the line in series with a resistance, and has a capacity that will allow of its being stalled for any length of time without overheating. With locomotive standing still, the motor has sufficient torque to exert a pull on the cable of some 30 lbs., and the instant the locomotive moves forward, the motor begins to reel up cable. Its tendency at all times is to produce a peripheral speed at the rim of the reel that is higher than the linear speed of the locomotive, so that there is a constant tension on the cable, which insures its being wound compactly on the reel. When locomotive changes direction and unreels the cable, the motor becomes a series generator and has sufficient counter-torque to produce a tension of about 40 lbs. on the cable. This insures the cable being payed out evenly and dropping along road-bed without producing any kinks.

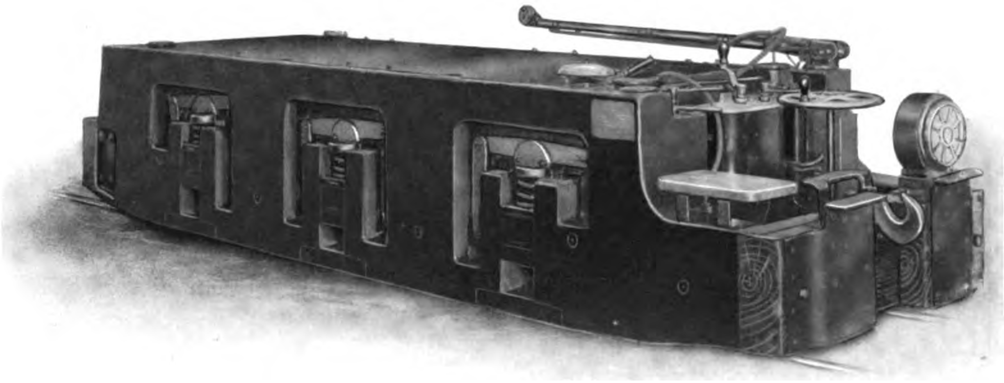


Fig. 5. 10-Ton, 3-Motor Locomotive

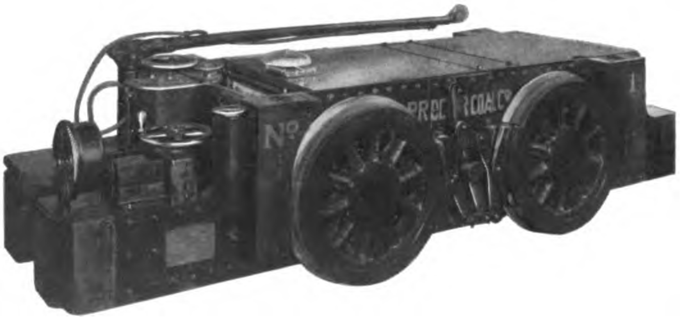


Fig. 6. 5-Ton Locomotive, Steel Plate and Angle Iron Frame Construction

As will be seen from the sketch, the reel proper is supported on top of the motor frame on ball bearings; the motor armature also rotates on ball bearings, and beyond applying a little grease to these bearings occasionally, no other lubrication is needed.

An experimental reel has been in operation at the mines of the Temple Iron Company for the past four months, and a report has just been received from the mine to the effect that the operation has been entirely successful; as there is no shifting lever or other mechanism to look after, the motormen greatly prefer it to the old style reel.

In Fig. 5 is shown a ten-ton, three-motor locomotive. The valuable feature of this type is that its weight is distributed on six drivers, and that it can therefore be operated on much lighter rails than the two-motor locomotive of the same weight wherein the weight is concentrated on four wheels. In the older mines, as the workings are carried further and further into the coal vein, the haul to the shaft mouth becomes longer and longer, and in many cases reaches as high as six or seven miles. In such cases, economical operation demands that the maximum possible amount of coal be hauled per trip; long heavy trains are therefore coming to be a necessity. Owing to the light rails, a heavy locomotive with a minimum weight per driver is usually the only thing that will handle service of this character.

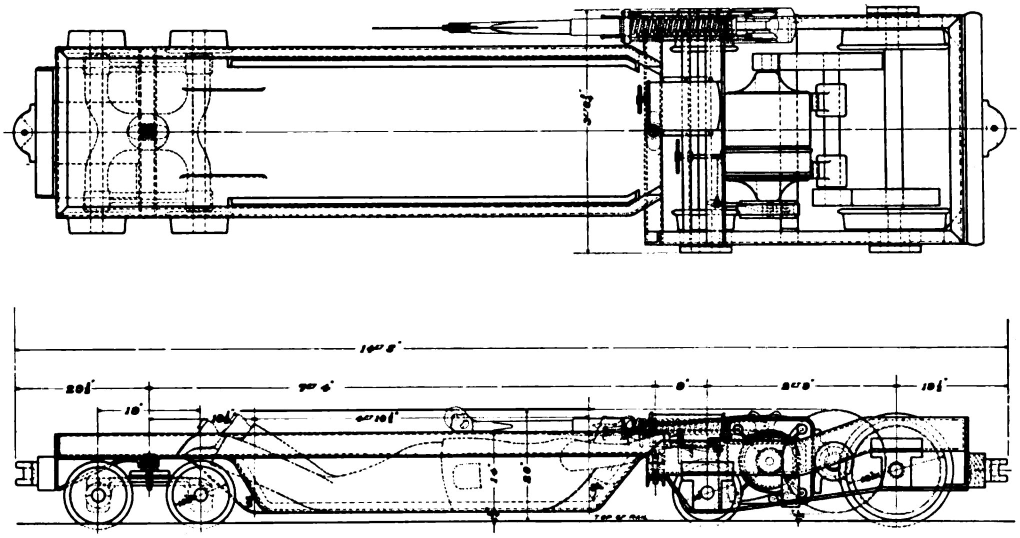


Fig. 7. Special Locomotive Designed for Extreme Conditions

The system of equalizing levers, which suspend the weight on the axle box springs, insures that the weight is evenly distributed between all three pairs of drivers, thus providing equal loads on all three motors. This locomotive also rides very much more easily than a two-motor type, and the shock and resultant wear and tear on the rails and roadbed are greatly lessened. In order to prevent cramping when rounding sharp curves, no flanges are used on the center pair of wheels.

A departure in the design of locomotive frames was made last winter when two five-ton locomotives were built having frames of steel plate, instead of the usual cast iron ones. One of these locomotives is shown in Fig. 6. The side frames are built up of steel boiler plate reinforced along the upper and lower edges with heavy angle iron. End frames are made of channel iron provided with wood buffers. This style frame can be used successfully on locomotives up to about 6½ or 7 tons weight. The design is also very flexible, since it allows wheel-base, over-all length and over-all height to be changed to meet the varying requirements of different customers without involving any pattern work.

The recently designed locomotive shown in Fig. 7 is an illustration of the extreme conditions that are sometimes imposed in mine work, this being a 2½ ton locomotive with an over-all height of but 20 inches. It is proposed to use several of these machines in Tennessee where the coal vein is very thin. In mines of thin vein, operators do not spend any time or money in cutting anything else but coal; this results, when a thin vein is encountered, in a tunnel of very low roof. By using 18-inch drivers and a small box frame motor, the design of the main driving truck was brought within the 20-inch limit. In order to allow motorman to clear roof also, it was necessary to connect, behind the main driving truck, a sort of cradle truck in which he could lie down at full length and still have his hands free for operating controller and brake wheel. The motor shown is a 10 h.p. box frame type and is connected to the driving axle through double reduction gearing.

This locomotive will have a rated drawbar pull of 800 lbs. and a speed of 5 miles per hour.

GEM HIGH CANDLE-POWER UNITS IN THE NEW WHITE FACTORY

By F. W. Willcox

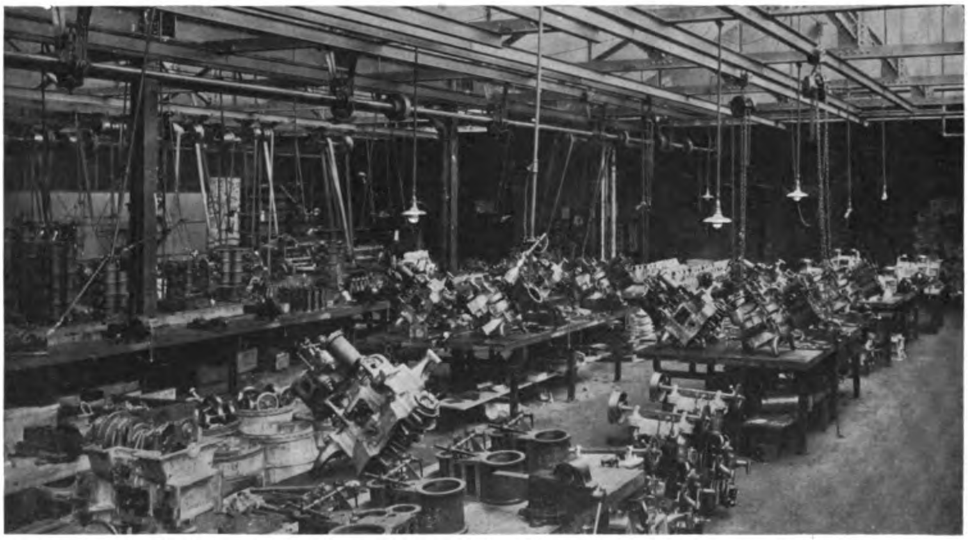
The new White factory at Cleveland, Ohio, in which the White steamer automobiles are made, is a model factory in design, equipment and organization. As a site for the new factory, thirty acres were secured in the eastern part of Cleveland, adjacent to the park system and bounded by the tracks of the Lake Shore & Michigan Southern Ry. In order that there might be easy communication between all parts of the plant, the plans were so drawn as to provide a covered thoroughfare connecting all the units of the structure, and of such a size as to permit the largest trucks to handle material at the doors of the several buildings comprising the factory.

Another consideration kept in mind in designing the plant was the provision for additional space for increase of plant, allowing for additional units to be made to the present buildings without altering the symmetry of the plant.

One of the special features in the construction of the plant is the provision for ample illumination, which secures an abundance of light in every nook and corner. Many manufacturing plants of great size are equipped with modern and expensive machinery, but almost all of them are defective in not giving their working force sufficient light to secure the best results from their labors.

The buildings are twelve feet in the clear below I-beams, and the supporting columns are spaced 30 ft. apart from center to center, giving an appearance of roominess which is rare in manufacturing plants. When such a concern undertakes the erection of a new factory, it is to be expected that a notable structure will result.

The factory is not only spacious but abounds in ample illumination afforded by the one-story type of construction with saw-tooth roof, making every part of the factory as light as day. It is particularly gratifying, therefore, to note that for artificial illumination, replacing daylight after nightfall, this company has adopted the GEM high candle-power units, which, as shown in the illustration, are scattered throughout the various factory rooms, suspended by extension rods from the girders above. Each lamp is equipped with the D holophane reflectors and pull-chain socket. The extension rod is clamped by an adjustable holder on the ceiling girder so that the lamp can be raised or lowered to a desirable position over the work in hand. In this way the lamps are



Section of White Factory Lighted by GEM Lamps

kept out of the way of the workman and machinery, and at the same time are employed in the most effective way to give the desired illumination exactly where it is wanted, without attempting to depend on simple general illumination by lamps placed directly on the girders, or above the line of the shafting.

The White factory has been built to accommodate a business of seven years' growth, in which the White steamer has attained to an enviable reputation among automobiles. The White Co. is an offshoot of the White Sewing Machine Co., the latter having been in business for the past thirty-five years.

SOME FUEL PROBLEMS

By Herbert M. Wilson

Chief Engineer Technologic Branch, U. S. Geological Survey

Doubtless all of you have been interested in the newspaper and magazine articles that have recently been published concerning the conservation of the natural resources of the United States. This subject means a great deal—much more, I think, than many of us realize, because it is so new and unfamiliar. The United States has such a vast area, and is so rich in lands, in timber, in minerals of all kinds, and in water, that the States and the Federal Government have been giving them away to all who wanted them, with such prodigality that the few whose duty it has been to take stock of our possessions have come to realize the fact that, before we know it, we will have no land to give; nor water, nor minerals, nor forests.

President Roosevelt, with his customary public spiritedness and foresight, has become greatly interested in this subject. A Waterways Commission was appointed about a year ago to consider how the waterways of the United States might be somewhat improved. When the members of that commission came to travel over the country and observe the small portion of the original natural resources which the country as a whole possesses, they brought the matter to the attention of the President, and it was decided to call a conference in Washington, of the governors of all the states, to consider what might be done with a view to conserving the remaining natural resources. This was an extraordinary procedure—something which has had no parallel nor precedent excepting the one great historic precedent, when in 1783, I think it was, George Washington, one of the greatest statesmen and engineers this country has ever known (we all know he was a great statesman, but that he was one of the greatest engineers in the country few realize), invited the governors of the various states to meet him at Mt. Vernon on the date which President Roosevelt has adopted for the convening of this conference in the White House; namely, May 12th to 15th.

On May 12, 1783, seven governors met at Mt. Vernon to consider what might be done to improve internal ways of communication, steam transportation, utilization of forests and minerals, and how the land should be disposed of to the new colonies and states. Nothing of moment came of the first conference excepting an exchange of ideas, and an adjournment was made to the next year, when there was a better attendance. The matter was then gone over again, but still nothing of moment was done; but at the third conference, in 1787, the constitution of the United States was drafted.

Now those who have been following the movement started by President Roosevelt for this conference, have come to appreciate many things they did not anticipate in the beginning. The facts are, that the people of the country in general, and of certain sections more particularly, are very jealous of the United States taking too lively an interest in any of the property within the borders of any of the states. When we talk of the government attempting to protect the lives of miners, or of doing anything toward the preservation of fuels on other than government lands, they at once cry "centralization of government," etc., and want to know where state rights have gone; therefore, the government at Washington must be careful if it would do its part in trying to preserve for the future the heritage of the people.

It was a wonderfully statesmanlike thought to bring together at the White House, where no conference had ever been held before, the governors of all the states in the Union, with their special advisors, to consider how this matter might be solved. By so doing, the outcome may be greatly affected; as a better understanding will be had on the part of the people in the states as to what such a movement may mean, if by reflex action it comes back from the states, than if anything had been attempted from the central government.

I think there are about 1,400,000 millions of feet, board measure, standing timber in the United States, as near as can be estimated by the Forestry Service. The cut of timber for all purposes is now something like 100,000 millions of feet, board measure, per annum. By simple mathematics, which we can always believe, in 14 years all the timber in the country will have been used. That, of course, is neglecting the preservative measures being started, and the reproduction of timber. It is certainly a case which calls for urgent action, and everything that can be done in the way of legislation in states and central government should be put in operation to preserve to us something of the lumber which is left.

We have 25,000 million tons of iron ore in the world. This estimate is the result of a recent census by the Swedish Government, corrected by the Geological Survey for the United States. At the present rate of increase in consumption over the rate of increase in the last 20 years, 200 years at the outside will see the exhaustion of our iron supplies. The question is, what are we going to do about preventing its waste? The same is practically true about the fuels. We know pretty much everything there is to learn in this country and abroad about the extent of our fuel deposits.

The public lands have practically all been taken up and settled, and have gone into private ownership; that is, those which are the most important and available. There are vast areas on rocky slopes of mountains, and vast areas in deserts and swamps, but of the agricultural lands, comparatively few acres are left for settlement. One of the means whereby the area of fertile lands may be added to is irrigation. There is now a considerable amount of land under irrigation which, a few years ago, was arid land, where hardly any rain falls—probably under 10 inches per annum; land on which nothing grew under these conditions but cactus and sage brush; yet when water is brought to these arid wastes and poured on them they produce the most prolific crops of any lands in the country, because they are not subject to an overdose of water and to too little sunshine. They always have sunshine, and get as much water as they need. The Reclamation Service estimates that within the present generation there may be brought under cultivation 12 million acres not already cultivated, which is sufficient to support an additional million of inhabitants.

Still another source of agricultural land is the swamps. There are over 80 million acres of these. Formerly there was a much larger area, but in a small way farmers have taken the smaller swamps—those most easily drained with the least expense—and have drained them; and there are under cultivation, millions of acres of swamps where people would not think they had existed. There is no reason why these swamps may not be reclaimed with the aid of sufficient funds and engineering study, as has been done with arid lands; and it is believed that within a generation, if the reclamation of swamps be put under government supervision with sufficient funds, perhaps as much as 20 millions of acres can be reclaimed, thus adding to the population supporting area, land which could be used by say four million people.

The last of our great natural resources is the water. We have vast volumes of rain falling over the area of this whole continent every year, and running off into the ocean; hundreds of millions of horse-power going to waste that might preserve our fuel supplies, and thousands of millions of cubic feet of water that might be used for agricultural purposes, for domestic use, and so on. We have not begun to scratch the surface of what may be done. As with all our natural products heretofore, it has been given away. All who wanted water-power were at liberty to get a site for a dam, or for storage purposes or power purposes; erect a power plant, sell the power, and make the profit off the water which really belonged and still belongs to the people. Probably four million horse-power (rather a rough guess, as we have no reliable census figures) are developed in the country today from water power. It is not improbable that within a generation, under proper encouragement, 10 million horsepower may be developed through storage at suitable places, perhaps three times that amount. It is time that we began to make use of this water and to save its loss. It means that actual value is going into the ocean every year.

One of the possible means of preventing the waste of timber is by encouraging the use of substitutes. Iron, of course, is a substitute which has been pretty generously used in the past; but it is expensive material, and is rapidly growing scarcer, as I have shown, and is therefore not really a substitute. Probably the real substitute and preventive for the waste of our timber is going to be found in concrete—reinforced concrete construction in particular—and the Government is engaged in the testing of structural materials, as well as the testing of fuels. Of the structural materials to which the Government has devoted its attention so far, concrete and reinforced concrete seem to be the most encouraging. It is a well-known fact that much reinforcement, and consequently much money, is being wasted today in reinforced concrete construction, because the use of the material is new, and it is not known exactly what it will do, nor how much it can be relied upon. It is estimated that from 4 to 10 per cent. too much material is being used. Any reduction of material means a reduction in cost, and the relative prices of reinforced concrete construction and timber construction are now approaching so closely, one to the other, that in the West, where timber is more expensive, concrete is now an open and recognized competitor with wood. The building operations of the United States last year amounted to something like $650,000,000, and from $250,000,000 to $300,000,000 of construction is burned up every year. Adding to this the expense of preventive measures, fire departments, fire insurance, etc., over $500,000,000 is lost every year in fires—as much, nearly, as we spend for new construction and reconstruction. In the United States the fire tax last year was nearly $2.50 per capita. In many European countries, masonry, stone, and less inflammable materials generally than we use, are employed, and the average for the whole of Europe last year was $0.33. There is no reason to doubt that with the increased use of uninflammable materials we shall be able to bring our fire tax down to this. I think I am conservative in saying that, if we could compel the use of none but uninflammable materials in buildings in this country, the saving on fire loss within a couple of decades would more than pay for the difference in price of construction.

The Geological Survey Structural Material Testing Laboratory at St. Louis has made 53,000 odd tests of structural pieces in the last three years, including cubes, columns, beams, etc., of cement, mortar, concrete and reinforced concrete. Some 2,000 specimens were columns of full size, and as many more were building blocks, also of full size. A vast amount of information was gathered which we have every reason to believe will lead to a much more general use of reinforced concrete in building construction.

Having briefly considered the general subject of the conservation of the resources of the United States, I will now pass on to the matter of fuels.

The production of coal in the United States last year was about 400 millions of tons, as against Great Britain's 300 millions. The production of anthracite has not kept pace with the production of bituminous, and as anthracite is largely used for domestic fuel in the Northeast, these facts give one an insight into why the price keeps on going up. The production does not at all approach the demand, and everything is being done to encourage the use of bituminous coal. One purpose of the fuel testing plant of the Federal Government is to determine how to use the low grades of fuels most efficiently. At the present increased rate of consumption, on the basis of the increase shown during the past twenty years, in approximately 200 years all of the coal fuel in the United States will have been used up. This again presupposes that we shall not learn to use it any more economically than at present, and that we shall find no substitutes. The Technologic Branch of the Geological Survey has been engaged in a very careful survey and study of the coal deposits of the United States, and this investigation largely represents the work of the Department to-day.

The chief anthracite deposits of the United States are found in Pennsylvania. There is, however, anthracite in other places, including West Virginia, Ohio, Kentucky, Tennessee and Alabama. West of the Mississippi river there is good bituminous coal, rich and volatile; also great deposits of lignite. We are just beginning to realize how vast the areas of lignite are. In Utah an opening is being mined through a seam 20 feet high, wide enough for four tracks to run in parallel. The coal is dug out as high as the men can reach with their picks, and it is nice, clean coal.

Under the supervision of the President, the government is now engaged, and has been during the last year, in mapping out the coal areas, locating the coal deposits by quarter sections on the public land systems, making borings and geological studies, and sending in samples for determining the fuel value. And instead of giving away the land at $1.25 an acre to those who would come and get it, it is proposed to sell the coal lands at $10, $20, $50, or $100 an acre, according as to how the coal assays.

Coals from all these regions are being sampled by skilled field inspectors who belong to the Department, and who personally supervise the mining and make reports on the method of shipping. Cars are shipped under seal to the testing laboratory, where the coals are tested in such a manner as to get a comparative estimate of their fuel values for various purposes. It would be impossible to make mechanical tests, on a large scale, of coals from every little coal field; but having made test in various ways on typical coal in carload lots, and having a chemical analysis made at the same time, it is very easy to tell what other similar coal will do. We are therefore reaching the point, after having made 400 tests in the United States and Alaska, where we can tell, by making a chemical analysis, what a certain coal will do.

The vast areas of coal in Ohio, West Virginia, Indiana, Kentucky, Tennessee, and the West, and the great areas of lignite, show that, though we are mining our coal too rapidly in Pennsylvania and prices are going up because we are producing largely there alone, there is coal in great areas as yet practically untouched. In these investigations which the U. S. Geological Survey is conducting, four lines of work are pursued, *viz.:*

1. Prevention of waste in the production of coal for marketing; *i.e.*, waste in mining, waste in loading, and waste in the leaving of coal which is valuable because it does not come up to a certain commercial standard of specifications.

2. Fuel investigations, in which the Department is charged with the purchasing and analyzing of the coal for the Government. It used to be the practice of the Government, as with most commercial organizations, to buy coal according to the localities and mines from which it came. That is not done now. The coal is tested and analyzed to determine the number of British thermal units, and is bought on specifications which enable the government to get what it pays for.

3. Increasing the efficiency in the utilization of the fuel after it reaches the furnace, and learning what can be done to increase its efficiency, so that a little more power may be got out of the same amount of coal.

4. Determining what means there are for using coal (besides burning it under a steam boiler) which will produce power more economically than at present.

In mining coal it is not uncommon to take a large seam in a region easily workable and, because it will be more profitable, mine that first, leaving other seams untouched. In so doing, as time goes on, the timbers supporting the walls give way and the earth falls in, shutting out all possibility of taking more coal from the lower seam, and also rendering it practically impossible to work the upper one. Again, in many mines, as much as 50 per cent. of the coal is left in the walls, partitions, roof and floor. Only the best, high grade coal is taken out, lots of good coal being left behind. A careful estimate, made from a general examination all over the country, indicates that on an average 50 per cent. as much coal is left underground as is taken out. In other words, on the 400 million tonnage of last year, 200 million tons were lost, left in the mines and wasted on dumps, and can never be recovered.

As an incident to the study of the waste of coal in mining, it is found that a vast amount is lost by the use of explosives—using a bad explosive or too much of it. Incidentally, these explosives destroy human life.

It is a curious circumstance that the Geological Survey may not consider the question of human lives lost, and it is only because members of the Department incidentally happen to find it out that it is made public. In the United States for the last five years, the average number of men killed in mines for every 1000 men employed, was 3.39; in Great Britian 1.03; in Belgium, 1.4; and in other places, less than 1. In Belgium, where mining is more dangerous on account of the greater depth of mines, the government took the matter under consideration some time ago as to the cause of these deaths (as is done in those European countries where a higher value is set on human life than in this country) with a view to restricting the use of certain explosives and of limiting the placing of shafts, etc., and it has been able to reduce the death rate from 3½ to nearly 1. In Great Britain the study of prevention of death from mine accidents and explosions was taken up thirty or forty years ago. In the beginning, Great Britain had a death rate nearly as high as ours, but by 1895 it had been reduced to 1.5, and it has been slowly falling off since.

The means which the U. S. Government is advocating for preventing and decreasing the death rate include the prohibition of the use of certain explosives which give a long flame, as these explosives will ignite the gas and coal dust in the mines. Certain others can be used in the presence of a great amount of coal gas and dust, but as the flame is so short they will not cause these to ignite.

The Technologic Branch of the Geological Survey is erecting a large gallery simulating the conditions of a mine, placing timbers therein and dividing it into many compartments, where it is proposed to test all kinds of explosives in the presence of all kinds and conditions of gas. The Department is also at work studying the gases in mines.

After one of the mine explosions in West Virginia, the Department's specialist went into the mines and made chemical analyses of the coal dust and gas; and it is now known pretty well what kind of gas there is in many of our mines, and what kind of gas occurs after explosions. The Department is therefore ready to reproduce the conditions in the presence of various kinds of explosives.

Where mines are dusty, certain preventive measures can be taken to keep down the dust as it is quite as explosive as coal gas. Dust explosions of various kinds in cement mills, etc., are often heard of, and in Minnesota a few years ago a flour mill was blown to atoms by such an explosion.

The fatalities in mines are not all due to explosions; these are only a small per cent. of the causes of deaths. The earth falls in, the walls give way, etc. These accidents; however, are largely superinduced by the use of too much explosives—too heavy charges—which shake the walls and earth and cause them to fall later on. The use of a proper amount of explosive mixture of the right kind will do away with these accidents to a certain extent.

We wonder a good deal about the matter of ventilation. Many theories have been advanced, but we are finding that over-ventilation of a mine can take place, especially where there has been careless or ignorant bratticing. Certain galleries are bratticed off to start the flow of air in certain directions, and by so doing enough air is mixed with the gas to produce an explosion when the open flame of a lamp is brought in contact with it. Many of these explosions occur when great quantities of dry air are being forced into damp mines for drying them out. There is, of course, a large amount of coal dust present, and in this way an explosion may follow from over-ventilation.

An explosion occurred last fall in a mine near Pittsburg, where the galleries ran everywhere, and a great area is honeycombed. Men were killed throughout all that area, even at the entrance, the force being so great as to cause death at a considerable distance from the explosion.

In the case of an explosion in Wyoming a short while ago, the force was so great that huge timbers near the entrance were thrown several hundred feet. There was a succession of three explosions at least, one causing the discharge of another at intervals of several hours.

The rescue corps for taking out the injured make headway slowly. In Europe they have gone further than we have in the way of life preservation, and have various kinds of harness.

Coming to the purchase of coal for the government, this amounted to nearly 1,500,000 tons last year, and cost about $6,500,000. I may here say that the cost of coal for the whole country last year was something like $500,000,000.

As I said before, it had been the custom to purchase certain coal for the government because of its coming from a certain mine in a certain region. This method has been discontinued, however, and the Government now purchases coal on specification. Last year something like 60,000,000 tons was purchased in Washington on specification. Specifications for anthracite, providing for the ash content and not taking into account the B.t.u., were adopted as a basis. In all purchases of bituminous coal the B.t.u. value of the product is considered as a factor in the specifications. Deliveries of coal at 40 government buildings in Washington, and to a great many other buildings, custom houses, etc., throughout the country, were paid for on the basis of samples taken by inspectors from such deliveries. Three men are kept busy in Washington sampling for 40 buildings. Samples are sent to the chemical laboratory of the Department and analyzed, and if they come up to specification, and do not fail in ash content over 1 or 2 per cent. either way, they are paid for at contract price. If they fail by more than 2 per cent. (for this year it has been fixed at 1 per cent.), there is a deduction in the payment; and if the coal has less ash than 1 or 2 per cent., there is a premium paid to the contractor. We are therefore paying for our coal according to its heating value—according to what there is in it, and not merely because it comes from a certain mine. The contractors began to deliver good coal to the government. In 1907, before the specifications went in, the average of ash in anthracite furnace coal was 10.4 per cent., and in the winter just closed the average was 9.7 per cent., a material falling off. In stove coal there was a considerable falling off in ash. The whole purpose of the scheme was not to make money, but to compel the contractors to deliver what they were contracting for, and to get good coal.

Another effect of this method of purchase has been to encourage the use of low grade coal. Hardly a particle of buckwheat or similar coal, and the cheaper anthracite, was burned in Washington until this plan went into effect. Now buckwheat can be had with so little ash that there is great profit in burning it. A reduction of over $15,000 has been made in the fuel bill in one year.

One of the lines along which the Department is experimenting for the conservation of fuel is the finding of ways for coking coals which it has been supposed would not coke. In Colorado, New Mexico, and all that country where silver, copper, etc., is smelted, coking coal and metallurgic coke is obtained from the East, where a few concerns control the few mines where coking coal is obtainable—a so-called trust. The Department got shipments of coals from different mines, sent them to a washery and coking plant in Denver, and found that by washing the coal it would coke to good advantage. In European countries the coal is washed for from 3 to 6 cents a ton, but through the Middle West the cost is as high as 10 to 15 cents. Washing is essential to the coking of low grade coal. The coals from Colorado, Utah, Wyoming, and all that region, were washed last summer, and the Department succeeded in making very good coke from 40 odd coals, representative of as many different fields; in fact, all fields but two, whereas only two were known before.

Everywhere outside of the anthracite region we are familiar with the black smoke stack—it is unhealthy and uncleanly. Black smoke is a sign that coal is not being efficiently used and economically burned, and is one of the indications of waste. It is not only black carbon that is going out of the smoke stack, but mixed with it are quantities of good gas. The fuel testing plant at St. Louis is making experiments and testing these coals in various ways to see what can be done to improve the efficient use of the coal. It is well known that, on the average only about 4.86 per cent. of the latent energy within a piece of coal goes into useful work, while the remainder goes up the smoke stack, into the ash pit, or is lost otherwise. Now with the gas producer, an average of 13.5 per cent. of the useful energy is obtained from the coal. Taking the latent energy used in converting the coal into electric energy and electric lighting, 99.857 per cent. represents the loss, and only about 0.1 per cent. of the useful energy of the coal is converted into electric light. What can be done to get more of that power into useful work.

In addition to the coking and washing of the coal at Denver, where each fuel was put through all its paces to see what could be done with it, it was burned under different types of steam boilers, with three kinds of stoking, and with forced draft, induced draft and natural draft. Everything was analyzed and weighed, and a careful record kept to determine just how to burn each coal most efficiently. The Department has been carrying this work on for years, so as to determine how much coal should be burned to get the greatest amount of energy out of it, and incidentally, how to send the least amount of smoke up the stack. It has been found that practically every coal—the very worst—can be burned in some kind of apparatus, with different arrangements, so that it will be practically smokeless, and produce the most energy for that particular coal. When this information is disseminated, the producers will be able to tell the people what kind of appliances to burn their coal in.

It has been found that all fuels can be converted into energy in the producer more efficiently than under the steam boiler. On the other hand, there are many things yet to be learned to make the gas producer a commercial success; but experimentally we find we can do better than with the steam boiler.

To this work is to be credited that side of gas producer practice in this country, of utilizing an ordinary producer plant for any kind of fuel. Automatic charging devices are coming into use and will cut down the labor bill.

The suction producer does not require a gas holder to equalize the delivery of the gas and make it more uniform. The gas is drawn by the engine at every stroke of the piston. The suction producers, in small units of a few hundred horse-power, are operating quite successfully on anthracite and coke, but not on bituminous coal. This latter coal gives off too much volatile matter and fluids, which would clog the engine.

In regard to the relative efficiencies of gas and steam plants, a very successful steam plant may give a little over 10 per cent. energy output, while the average steam plant gives only about 5 per cent. A steam plant gets about 0.287 electrical horse-power out of a pound of coal. In the gas producer plant, with the same coal, 0.961 horse-power is obtained, or over three times as much for the gas producer as for steam.

At this point we come to the problem of the millions of acres of lignite, which we do not know how to use, and which will not burn well in anything. It was discovered, however, that this fuel, which can not be burned under the steam boiler, operates as well in a producer plant as anthracite does under a boiler. We get 3.55 times as much from lignite when used in a producer plant as when worked with a heavy draft under a steam boiler, and 1.04 times the energy that the best coal will give under a boiler. Of course, coal in the gas producer will give better results than the lignite. This, however, opens up a way of using these lignites to good advantage.

Another way of utilizing lignite is by briquetting it—making little bricks of it. The fuel is fed into a hopper at one end of a mixer, where it is mixed with pitch. It is then thoroughly pulverized and passed into an oven which heats the material sufficiently to bind it together. After this it is passed through the briquetting machine and pressed into bricks. The Department found that, by taking Dakota lignite, and putting it under great pressure — 20,000 lbs. to the square inch—lignite bricks as firm as anthracite could be made. These bricks make a splendid domestic fuel. The low grade coals also burn efficiently when briquetted. With briquettes the furnace can be forced, and more fuel can be burned per square inch of surface, producing more steam.

Finally, I want to speak of one other line of experiment. The Department made a number of comparative tests of power produced from liquid fuel—denatured alcohol, gasoline, etc. At first, taking the gasoline engine, 2300 tests were made, and it was found that only about 0.8 of the amount of energy could be got with alcohol as with gasoline, and as gasoline is much cheaper than alcohol, this was not satisfactory. The Department, however, finally worked up the use of the alcohol engine until ultimately they got right along, day after day, gallon for gallon, the same results from alcohol as from gasoline. The alcohol produced just as much power as the gasoline did, and that in the face of the fact that gasoline contains nearly 20,000 B.t.u., whereas alcohol contains but little over half as much. The denatured alcohol is not the high priced ordinary commercial alcohol; it is relatively cheap. Gasoline is getting scarcer every day. It comes from the Standard Oil Company as a by-product, and the petroleum resources are not unlimited. Alcohol, on the other hand, may be manufactured from vegetables, and every gallon of alcohol used encourages somebody to make another gallon. One of the interesting features is the fact that, in countries where mineral fuels are most scarce, as in the tropics, alcohol can be most cheaply produced. Alcohol may be obtained very cheaply where sugar cane is grown. There are many other tropical vegetables now hardly used at all, which could be very advantageously utilized in making alcohol; therefore, it is encouraging to know that we are only at the beginning of the alcohol problem, and that there may be a great field for alcohol as a substitute for other fuels which are becoming more scarce.

HEAVY TRACTION GEARING

By John Liston

The development of modern electrical railway systems has involved a continued increase in the size and weight of both cars and equipments in order that the high speeds now demanded in this service may be maintained. As a consequence of these conditions, the augmented stresses to which the teeth of motor gearing are subjected, combined with the limited space available, have rendered the strength and wearing qualities of gears and pinions important factors in the cost of operation.

In order to successfully meet these conditions without an excessive increase in cost, the General Electric Company has developed a highly efficient gear (see Fig. 1), which consists of a forged steel rim or tire, mounted on a cast steel center so as to form what is practically a one-piece gear, as a pressure in excess of 200 tons would be required to force the rim off the cast center. This combination not only gives added resistance to wear on the gear teeth, but permits a rim to be replaced when finally worn out, with a minimum of delay and expense.

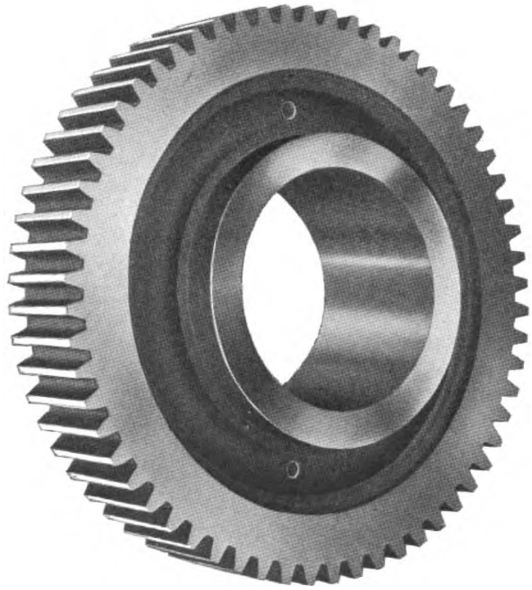
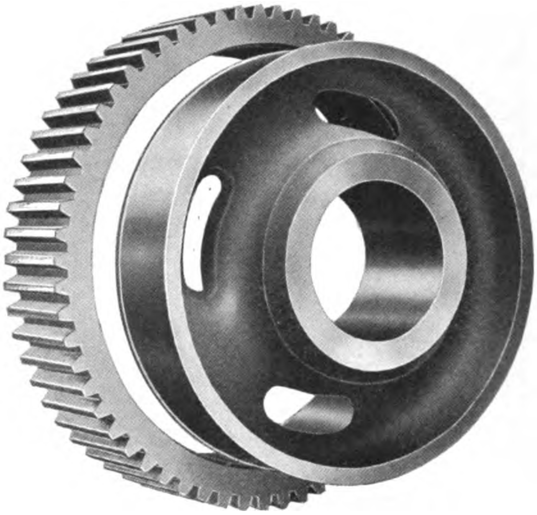


Fig. 1. Railway Motor Gear with Steel Tire and Cast Steel Hub

The success which this form of motor gear has met with in actual service is indicated by the fact that during the past three years it has been installed in original equipments on many of the most important electric railway systems in the United States, among these being the Interborough Rapid Transit Company; the Hudson & Manhattan Railway Company; the New York, New Haven & Hartford R. R.; the West Jersey & Seashore Railway Company; the Scioto Valley Traction Company, etc., in all of which the mileage records show graphically the increase in efficiency obtained by its use.



Steel Tire Gear Used by the Interborough Rapid Transit Co., with GE-69 Railway Motors

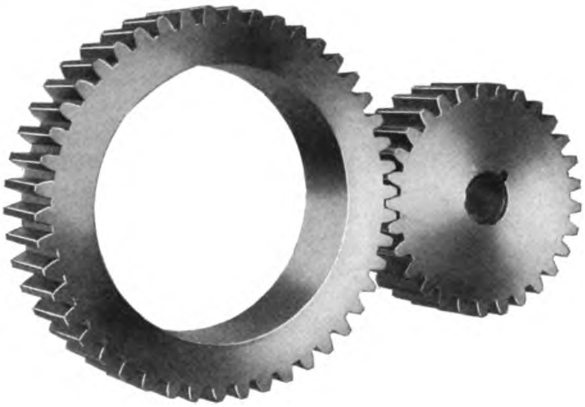
As a further development along these lines, the General Electric Company conducted a series of exhaustive experiments with the object of obtaining great strength with a uniform quality of metal, and they have now developed a pinion having physical characteristics of tensile strength combined with an elastic limit in excess of any product now on the market. These qualities are obtained without in the least sacrificing the element of toughness, so essential to the continued operation of heavy equipments.

This pinion is known as the General Electric "New Long Life Pinion—Grade 'F.'" This special "Grade F" steel after being machined, is treated by a process which avoids any possibility of distortion or internal stress while cooling.

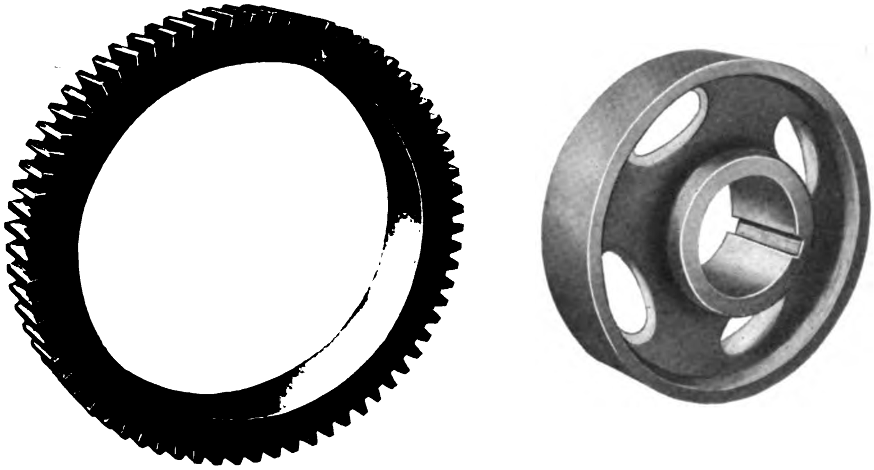
The increased strength obtained by this process insures an ample factor of safety over the stresses to which the pinion teeth are subjected in ordinary service, while the hardness of the steel minimizes the effects of abrasion and thereby reduces the wear from friction. As a result, there is a notable saving in the labor cost of renewals, and, in addition, the item of expense caused by interrupted service is materially reduced. There is also obtained a more nearly even wearing of gears and pinions.

This latter point is worthy of serious consideration, as the ordinary cast steel gear usually outlasts three soft pinions, with the result that during a considerable proportion of its life it is operating with worn pinions and under conditions of low efficiency, which add to the mechanical strain on the motor. In addition to this, the vibration and noise so frequently associated in the minds of the public with electric railway service, are largely due to the unequal wearing of gears and pinions. The "Grade F" pinion should, under average conditions, last as long as the cast steel gear, and as a result, outwear three ordinary grade pinions, with an obvious saving of the cost of two renewals as well as insuring operation at maximum efficiency.

The general appearance and method of assembly of steel tired gears are shown in the accompanying illustrations. In addition to this standard design, the General Electric Company manufactures the "Grade F" steel rim or tire so that it can be mounted on various forms of extended car wheel hubs or steel flanges to meet special conditions.



Steel Tire and Steel Hub of Gear Used by New York, New Haven and Hartford Railway Co., with GEA-603 Railway Motors



Gear used with GE-69 Railway Motors on West Jersey and Seashore Railway Company
The Gear is Shrunk on an Extension of the Wheel Hub. Gears and Pinions are Made of Grade "F" Steel

OUR COMPETITORS IN THE FOREIGN FIELD

By M. A. Oudin

Associate Manager, Foreign Department, General Electric Co.

Of the total exports of the United States, about one-third consists of manufactured goods. The official classification shows a much larger percentage, but this is because the list includes as manufactured articles certain crude materials exported in enormous quantities, such as refined oil and copper. The net figure representing manufactured goods, properly speaking, is disappointing. In this respect we are down on the list of exporting nations well below England and Germany, especially so as regards the steel and iron trade. High manufacturing costs and indifference to acquiring foreign business are largely responsible for this condition. Where consistent efforts are made to secure foreign business the superior merits of our goods may offset the disadvantage of high costs of manufacture. However, the best goods do not sell themselves, even at low prices, and where the prices are high as well, a domestic market is all that can be expected, and too often is all that is desired. Indifference to the unlimited markets abroad is the chief obstacle to be overcome in the expansion of our export trade.

We pride ourselves as excelling in the manufacture of steel and iron, and rightly so by reason of our technical knowledge and inventive ability. In some lines, our foreign business finds no such handicaps as those named above, the products possessing superior merit in design, together with competitive selling prices, and are pushed with the same zeal and intelligence as are brought to bear in domestic trade. In respect to mechanical perfection, American sewing-machines, typewriters, cash registers and machine tools are second to none, and command the markets of the world. It is well to add to this list another line of manufactured goods that has established itself as an international leader, not alone by reason of its superior merits, but also because of the intelligent and persistent methods by which foreign markets have been won and held. The combination of American ingenuity and engineering experience has advanced the art of making electrical machinery to a position where other nations may, and do, copy our methods without affecting their self-pride. The immediate result of our foremost position in the manufacture of electrical goods, and of their undoubted superiority, is our ability to maintain higher prices in some countries over our competitors' apparatus.

The same methods must be applied to the introduction of electrical goods abroad that experience shows to be successful with other lines. The most important point, and the first great necessity in establishing foreign trade, is to secure suitable representation in the countries to be invaded. Other points are assumed, as a matter of course, to have been attended to, such as a proper organization for handling foreign business, credit and banking facilities, experienced packers, shipping clerks, correspondence clerks, and mailing boys who will always put on sufficient postage.

No one kind of representation can be counted upon to secure the best results in all countries. Where the business in any country is of sufficient magnitude to warrant the establishment of an organization devoted exclusively to the sale of one line of goods, the manufacturer, as a rule, may profitably open his own headquarters there, selling direct to the local consumer. This involves a responsibility in granting credits, making collections, fulfilling all the local legal requirements, and an intimate knowledge of the business methods and morals of the community. A wide and extensive experience is necessary to carry out successfully such a business. The lack of it may lead to financial disaster. For this reason, in countries whose international credit is doubtful, or where unusually long terms of payment have become the rule, especially where the native language and methods are not easily learned, as in the Orient, it is good policy to do business through the medium of firms domiciled in such countries; and better still, those firms that have branch houses in the United States. In countries partially exploited, the business may be developed through local engineering salesmen working under the direction of local agents.

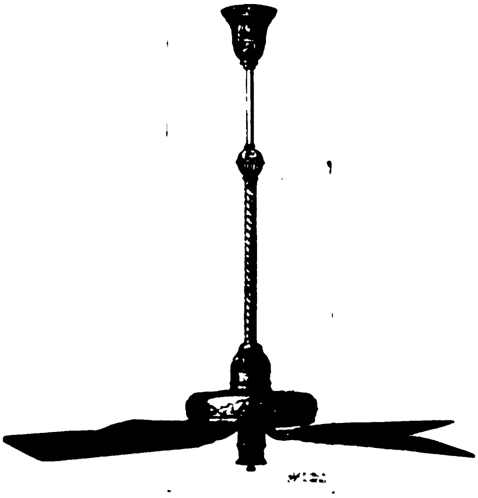
Personal representation is absolutely necessary to the successful exploitation of the electrical business. Salesmen must be engineers, and capable of inspiring complete confidence in prospective customers. It is worse than a sheer waste of time to attempt to build up a foreign trade by circular letters. Grain and potatoes and like staples may be sold at the expense of paper and postage, but to effect the sale of electrical apparatus requires the most intelligent representation and full engineering consideration.

In engineering thought, technical knowledge, and inventive ability, we find the reason for such little foreign success as we have had, and by means of the latter quality we have kept ahead of foreign imitators. Technical education abroad is becoming more and more practical, and engineering thought as applied to manufacturing is developing rapidly. We shall soon find our competitors meeting us on our own grounds. High costs will then be an insuperable handicap; hence, we must overcome our tendency to extravagance in all departments of manufacture, and look upon the conduct of foreign business as a vocation if we would increase or even hold our trade.

NEW ALTERNATING AND DIRECT CURRENT CEILING FAN MOTORS

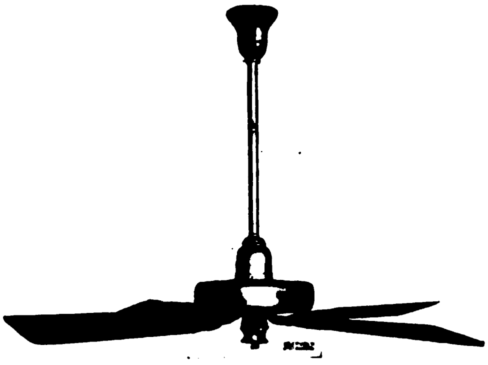
By H. S. Baldwin

Throughout the hot summer months, thousands of people are compelled by circumstances to remain in the offices and shops of our great cities, and their personal comfort and efficiency during this period are receiving more and more attention. If the toiler may not enjoy the breezes of shore or mountain, he may at least find a partial substitute in the electric fan, which tempers the heated air and renders life more interesting. In addition to this, there is a large demand for fan motors throughout the year in tropical countries, where the artificial circulation of air is a positive necessity, especially for the foreign residents coming from more temperate climates.



A.C. Ceiling Fan Motor—Ornamental

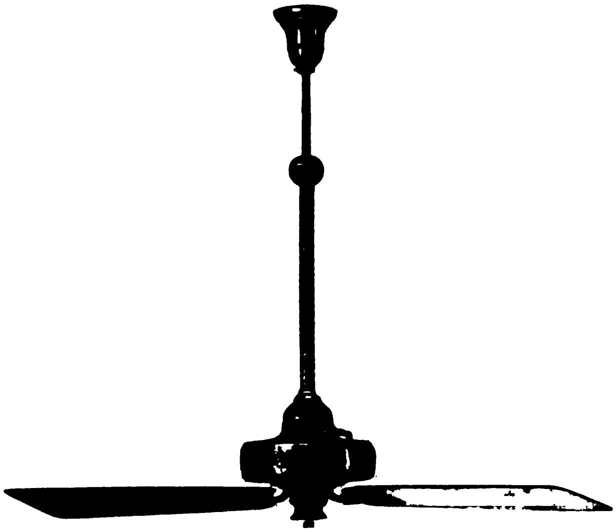
This season the General Electric Company has placed on the market a new line of alternating and direct current ceiling fan motors, which meet the demands of the trade to a marked degree, both as to attractive appearance and excellence of operation. Heretofore the ceiling fan motor adapted to operate on direct current has been considered distinct from that suitable for alternating current, and no attempt has been made by manufacturers to modify its stereotyped bi-polar design, with the conventional armature and bearing at the top and bottom. However, for manufacturing and commercial reasons, it would obviously be desirable to combine ceiling fan motors for both forms of energy in substantially the same mechanical structure, and this has been done in the General Electric 1908 ceiling fan motors. The accompanying illustrations will show the general external appearance of these devices. It will readily be seen that the alter-



A.C. Ceiling Fan Motor—Plain

nating current fan motor has been taken as a model for the direct current motor, and for this reason both may be described in parallel, except for electrical features.

By no means the least important consideration in the design of ceiling fans is the question of weight, which, in the new line of motors, has been reduced to the minimum; the 1908 alternating current motor of the plain type being 2 lbs. lighter than the corresponding motor of last year, while the latest ornamental motor weighs 13 lbs. less than its predecessor. The reduction of weight in the new direct current fan motor, as compared with similar motors of other manufacture, is even more marked, it being actually the lightest motor on the market. Some competitors' motors have over twice the weight.



D.C. Ceiling Fan Motor—Ornamental

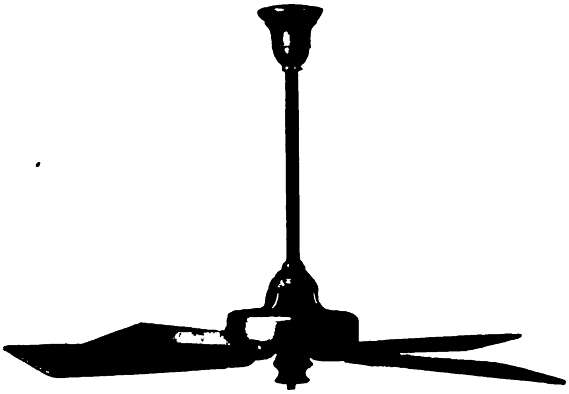
Great care has been taken in the refinement of electrical design of both motors, and in point of current consumption they compare favorably with those of other makes.

Much attention has been given to manufacturing details, with a view to producing motors which would operate substantially without noise.

This season's business in alternating current motors has been large, and the reports to date which have been received from the field would indicate that the General Electric Company have succeeded in producing fans which will operate in a manner satisfactory to the trade.

The ornamental alternating and direct current motors are distinctive in appearance. No attempt has been made to employ the conventional embossed thin sheet metal casing to cover up a rough motor. The ornamental features employed are dignified and rich. In mechanical design, the moving elements of both the alternating and the direct current motors is mounted upon a long ground-steel spindle, which is securely attached to the upper part of the frame. The thrust due to the weight of the rotor is taken up by a special ball bearing containing ten high-grade ¼″ steel balls, engaging with hardened ground and lapped washers. The lower washer is machined with a spherical surface to permit of the most accurate alignment.

A special system of lubrication has been worked out whereby the oil is raised from a receptacle to the top of the bearing by the motion of the rotor, whereupon it immediately returns to the bottom, giving constant and uniform lubrication while the motor is in operation. Good lubrication is highly essential, and to this end the Company is supplying with each motor an oil-can, containing the correct amount of the right kind of oil. The customer is instructed to put this oil into the motor at a point under the lower canopy, which is designated both by letters and suitable marking.



D.C. Ceiling Fan Motor—Plain

All motors of the new line are small in exterior dimensions, and are of the minimum size as to diameter and vertical height or thickness, thus emphasizing their light weight.

COLOR AND LIGHT

By Louis Friedmann

With the advancement being made in illuminants and illumination, the question of color becomes of greater importance. Heretofore we would not seriously consider colors by artificial illumination, believing it impossible to do so and obtain true color values as we do by daylight; but every advancement in illumination brings us nearer daylight, and we are now at a point where we can obtain and judge colors by artificial illumination with a marked degree of accuracy.

By improving artificial illumination, we are striving to obtain daylight effects, that we may view objects under such illumination with the same degree of accuracy as we do by daylight.

In our homes this is of little importance, as we have been used to an illumination at night distinctive from daylight for so long a time that it has grown to be natural, and it seems inadvisable at this time to attempt to change this condition, since an illumination differing perceptibly from daylight produces a relaxing effect upon one's sensibilities, which effect is very desirable in the home. No doubt, the change in the color of objects caused by the character of illumination in the home has much to do with bringing about this result.

In our commercial institutions an entirely different condition exists, as here the major portion of our work is conducted by daylight, and it is obvious that the artificial illumination should approach daylight as nearly as possible, in order to carry on our work with precision.

Analysis of Daylight

In passing through a triangular prism of glass or other transparent substance, ordinary white light is decomposed into a series of colors—red, orange, yellow, green, blue, indigo and violet—there being a certain proportion of each color. A ray of sunlight passing through such a prism is dispersed and produces a rainbow of color called the solar spectrum. White light therefore consists of a combination of these colored lights which have been separated by the prism, in their right proportions.

If a spectrum showed an absence of one color, or if the colors were not in correct proportion, the combination would not produce white light, and certain colors would not appear true under such a light.

If daylight were composed of but one color, all objects would appear of that color, or else black. Objects appear colored to us, depending upon their ability to reflect or absorb the colors of the light. Those which reflect all the colors of the light appear white, while those which absorb them all appear black. Those which reflect some colors and absorb others appear colored, the color depending upon which of these is reflected to the eye. In the dark there is no color, because there is no light to be reflected or absorbed.

Color is therefore dependent upon the light, and as our standards of colors are secured under white, or daylight, we must, in order to obtain and judge true color by artificial illumination, use an illuminant having as nearly as possible the same spectrum as daylight.

It is also important that the source of illumination should not be within the ordinary range of vision, so that we may see by reflected light, just as we do in daylight.

The question of color is of vital importance in many classes of business, such as clothing and department stores, where colored goods are matched and sold; printers and engravers who must make correct color reproductions; and manufacturers of high grade colored articles, etc.

The following advertisement, by a leading engraving establishment, indicates the importance of correct color in business:

> "WHEN YOU ILLUSTRATE your goods in Catalogues, Price Lists, Circulars, etc., why not show them " True to Life " in their natural colors? We would like to submit for your inspection some specimens of our three-color and quadri-color reproductions."

Color being dependent upon illumination, it is obvious that, if the correct illumination is obtained, the colors will be correct. To the business manager the question of a proper kind of illumination, especially where color is concerned, has always been a perplexing problem. He has not always had the opportunity of making a fair comparison of the various commercial illuminants.

At the last electrical show held in Chicago, the General Electric Company had on exhibition a "Color Comparison Booth," which offered the opportunity for seeing the effect of various illuminants upon colored materials.

This booth, was made up of four compartments alike in all details, with the exception that in each compartment a different form of illumination was placed. In some of the compartments, two illuminants were arranged so that they could be turned on independently. The various illuminants were as follows: Enclosed arc lamp; Nernst lamp; mercury arc lamp; and metallized, tantalum and tungsten incandescent lamps. Gas was not available in the building. These illuminants were adjusted so that the intensity of light was equal in all compartments, thus eliminating errors in judgment due to differences in intensity of light. In this booth one could simultaneously compare the same colors under the different lights, and it was remarkable to see how the colors of the materials were distorted by the illuminants, although most of these appeared to give a white light.

Under the mercury arc, which contains practically no red rays, red materials appeared black. Under illuminants which contained a predominance of yellow light, white materials appeared cream color; light yellow appeared deep yellow; gray appeared green, and so on. The conclusion arrived at by a concensus of opinion of those who viewed the booth was that the illumination produced by the enclosed arc lamp and the tungsten incandescent lamp came nearest to daylight, and were far superior to the others in producing true colors, the enclosed arc being the better of the two.

Several persons, expert in color work, satisfied themselves by mixing pigments, and by making other experiments, that they could obtain and judge practically true color under the enclosed arc. A souvenir color guide was given away, which consisted of a small card upon which was placed two pieces of colored cloth, green and gray, respectively, by daylight. These colors would match under lights having a predominance of yellow rays, while under the enclosed arc they appeared natural, as in daylight.

It seems to the writer that a color booth of this nature would be a valuable addition to the display room of any central station selling current for lighting, for, besides stimulating the use of electric current for lighting, it would allow the customer to see for himself which light best suited his business.

NOTES

The following item, which will be of interest to many readers of the REVIEW, appeared in the *Electrical World* of May 30th.

A THOMSON-HOUSTON REUNION—A movement was started during the N. E. L. A. convention to bring about a reunion of the men who used to be employed by the old Thomson-Houston Electric Company. The movement was given such an impetus by the members of the "old guard" present that it is now planned to have a general meeting of the men still living who were associated with the Thomson-Houston Company at any time from its inception until it was absorbed by the General Electric Company. In order to make it possible for all, no matter in what capacity they were employed, to take part in the event, it is planned to hold the meeting in January of next year coincident with the Chicago Electrical show. The object of calling together the old "boys" formerly engaged by this pioneer corporation is purely social, but it is expected much good will come to the participants. In order that some idea may be obtained of the number of persons that may be expected to join in the reunion, it has been suggested that each one employed by the Thomson-Houston Company up to the time of its absorption send his address to Mr. George Cutter, South Bend, Ind., who will keep the name and address on file Any suggestions on method of procedure, plans, etc., that may be made will be given careful attention. On the number of letters received will depend the preparations that are to be made for the event.

* * *

The following item indicating the superiority of the Curtis turbine appeared in the New York *Sun* of June 24th.

SCOUT "SALEM" BEATS RECORD

New Cruiser Makes 26.885 Knots an Hour on Her Trial

ROCKLAND, Me., June 23—Equipped with the Curtis type of turbines, the new scout cruiser "Salem" sped over the measured mile course off Owl's Head at the rate of 26.885 knots an hour on her official standardization test to-day, thereby beating the record made by her sister ship, the "Chester," equipped with the Parsons or English type of turbines.

The best mile made by the "Chester" was at the rate of 26.07 knots an hour and her average for the best five mile sprint was 25.1. The "Salem" averaged 25.954 knots an hour for her five best miles today, and when she steamed to an anchorage here this afternoon a broom was lashed to the masthead indicating that the new ship had broken all previous records of her style of vessel in the American Navy.

From information obtained from the builders, it may further be said that the total figures of the Navy Trial Board show that the "Salem" successfully completed her four-hour high speed run, making a speed of 25.946 knots per hour, and sustaining 26.01 knots for the second and third hour.

The "Salem" has also completed a 12-knot, 24-hour run for the measurement of fuel, and shows a consumption of coal of 4051 pounds per hour, at a mean r. p. m. of 164.11, with a brake horse-power of 1380, making the coal consumption per brake horse-power hour 2.94 pounds, and knots per ton of coal, 6.68.

Enameled Wire

A soft-drawn copper wire insulated with multiple coats of enamel
The insulation will not absorb moisture

The thickness of insulation is approximately half that of single cotton and two-thirds that of silk-covered magnet wire. This allows a larger number of turns on the same spool or same number of turns with a less weight of wire. The percentage of advantage of enameled wire becomes less in the coarser size and increases in the finer size. Enameled wire may be bent around a mandrel four times its own diameter without injury. Owing to the thinness of the insulation and its good heat conductivity, spools wound with enameled wire run at a lower maximum temperature and a lower average temperature than spools of cotton-covered wire under the same conditions. Enameled wire will stand a temperature of 212° F. without injury

These two spools are the same size and each contains 8400 turns of No. 28 B. & S. Copper Wire

This winding of Single Cotton-Covered Wire is 15/16 inches deep and weighs 2.8 pounds

This winding of Enameled Wire is 9/16 inches deep and weighs only 2.2 pounds

The use of enameled wire in this case saves 21 per cent. in weight of wire

COMPARISON OF DIAMETERS

Size B. & S.	Single Cotton-Covered	Single Silk-Covered	Enameled
24	.0241	.023	.022
25	.022	.021	.020
26	.020	.019	.0175
28	.0166	.0156	.0140
30	.014	.0126	.0113

COMPARISON OF DIAMETERS

Size B. & S.	Single Cotton-Covered	Single Silk-Covered	Enameled
32	.012	.0105	.0092
34	.0103	.0086	.0073
36	.0085	.0070	.0062
38	——	.0060	.0052
40	——	.0050	.0042

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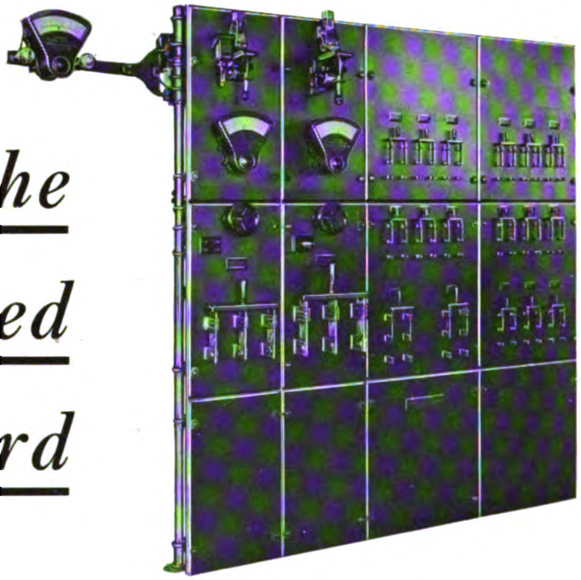

The Simplified Switchboard

The Three-Section-Panel idea has been reduced to practice by the General Electric Company

It is now possible for a purchaser to suit his switchboard requirements with stock sections combined to form his complete switchboard. He has choice of over 10,000 standard sections which may be ordered by Catalog Number and assembled to form more than a million different switchboards. Every conceivable requirement is met with standard stock parts which have been designed and manufactured with deliberation and care

Agents of this Company are prepared to show purchasers an assembled view of any switchboard made up of these standard parts

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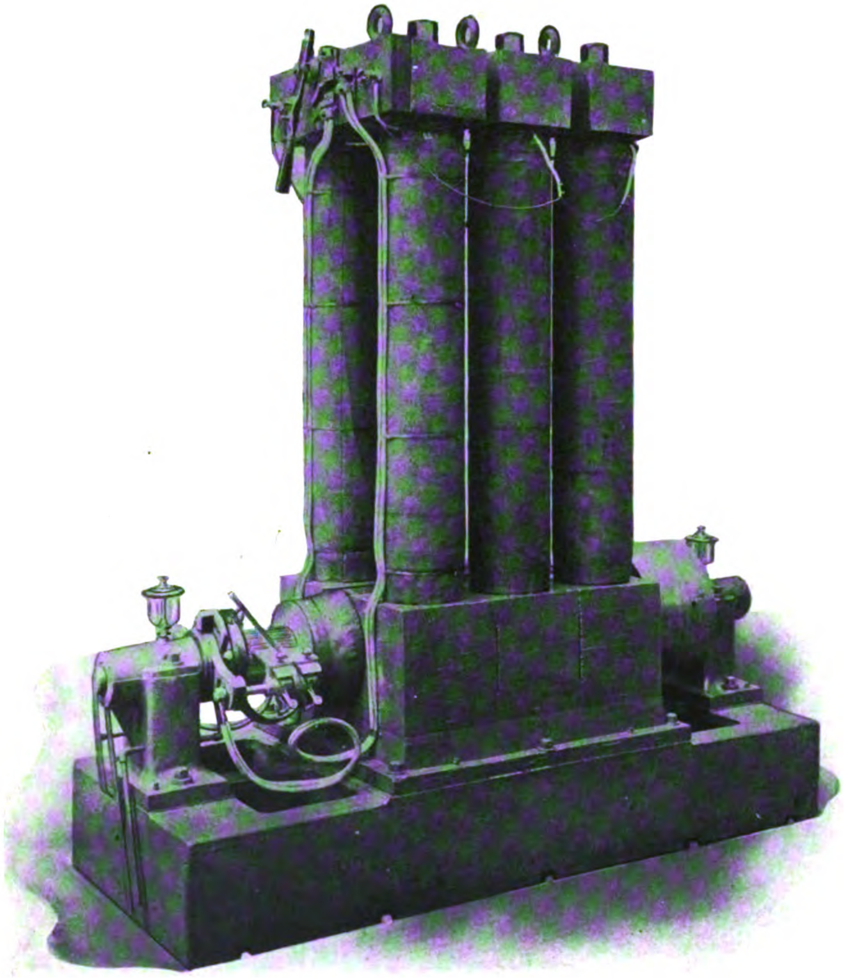

EDISON "K" DYNAMO — 1881
(See page 109)

We have factory capacity
for 35000 Tungsten Lamps a day—
Insuring present and future supply

GE Tungsten Lamps

Consume but ⅓ the current of ordinary lamps of equal candle-power **or** give three times the light for the same current consumption

The Tungsten Lamp is here—
Both in quality and quantity—
No waiting necessary—
Immediate shipments—all sizes

Supreme Brilliancy & Efficiency

Four GE factories that exclusively produce Tungsten Lamps:

HARRISON, N. J. NEWARK, N. J.
TOLEDO, OHIO E. BOSTON, MASS.

Order from our nearest office and get lamps promptly

THE G.E. TUNGSTEN LAMP

1¼ watts per candle supplied in following sizes:

32 c.p. - - - 40 watts
48 c.p. - - - 60 watts
80 c.p. - - - 100 watts

For 100 and 125 Volts

Ample stocks at the following cities:

ATLANTA DENVER NEW ORLEANS
BOSTON CINCINNATI NEW YORK CITY
CHICAGO HARRISON PHILADELPHIA
SAN FRANCISCO PITTSBURGH

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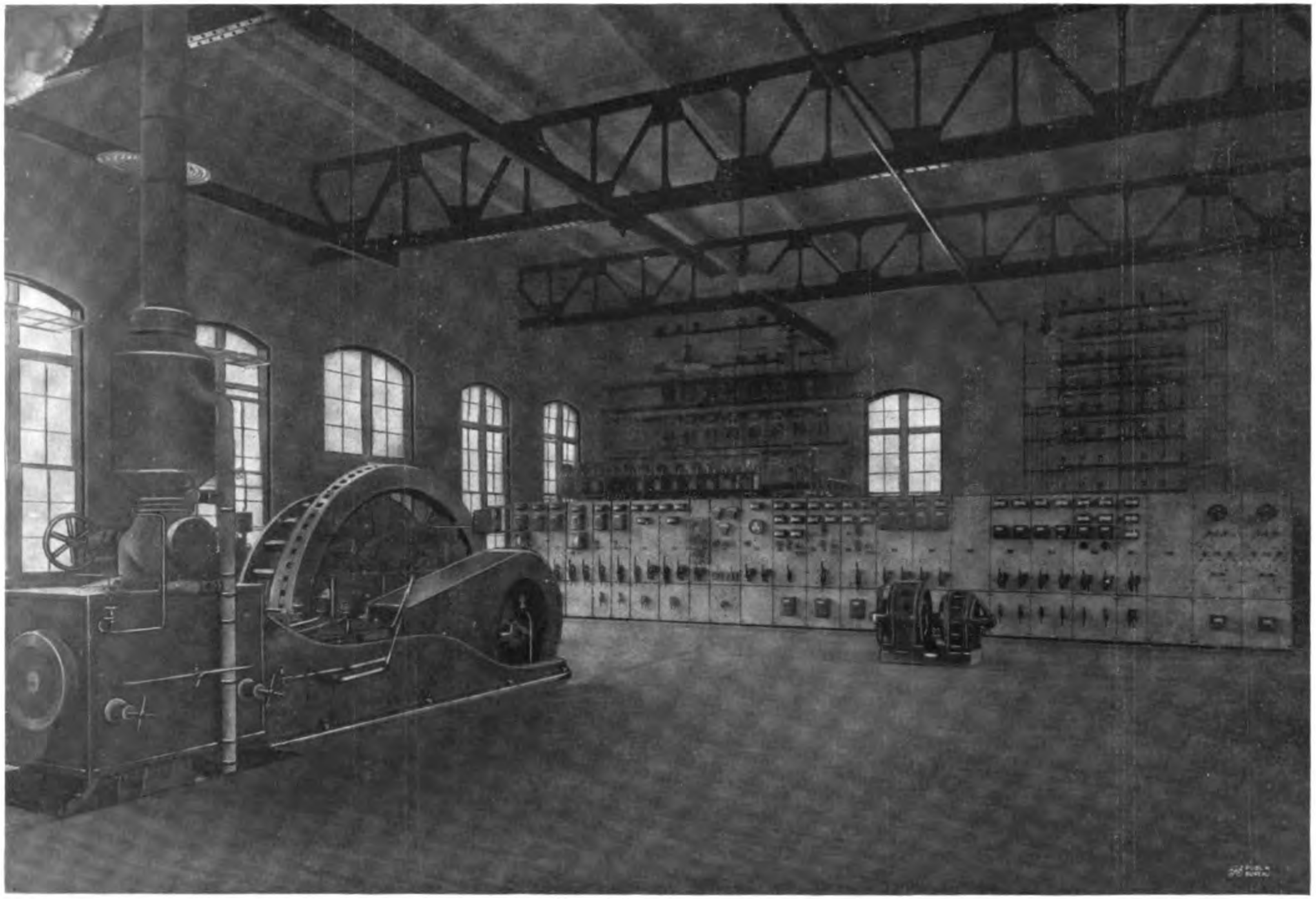

GENERAL VIEW OF POWER STATION OF GREENFIELD ELECTRIC LIGHT AND POWER CO.

(See page 122)

GENERAL ELECTRIC
REVIEW

ALTERNATING CURRENT UNDERGROUND DISTRIBUTION

PART II

By S. D. Sprong

The Elizabeth Street sub-station equipment is made up of three 2750 kw. static transformer sets, two 1000 kw. motor generator sets, and induction regulators. The switch and bus compartments are entirely of concrete. All switches are electrically controlled from a marble control board, seven panels of which control two feeders each, there being at present 14 feeders from this station. The remaining panels are for the control of the primary and secondary sides of the static transformers, and of the 25 and 60 cycle ends of the motor generator sets. Two 25 cycle feeders from Waterside to this station operate the motor generators, the feeders being provided with overload inverse time element relays. These feeders are usually operated independently. There are also three 7500 volt, 60 cycle feeders for the static transformers, these feeders being operated in multiple, and protected by overload and reverse current inverse time element relays. The purpose of this relay is to select a defective feeder and disconnect it at the sub-station end, and practice has shown that it satisfactorily performs this function. In the 146th St. station, where there are but two 60 cycle feeders, this type of relay has disconnected the defective feeder without disturbing the good one or interrupting the service.

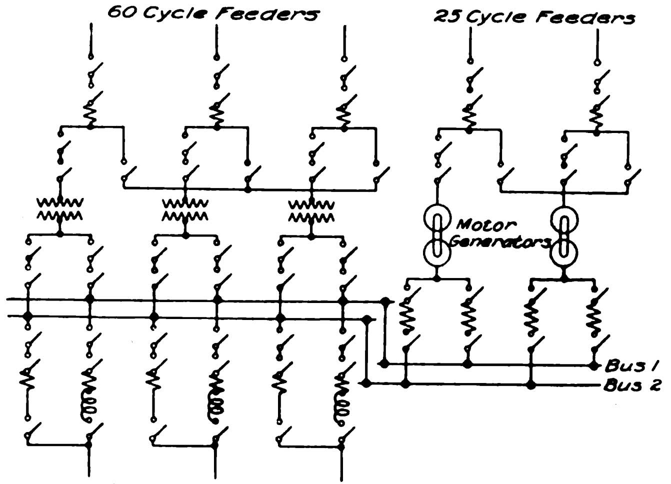

Fig. 10. Wiring Diagram of Elizabeth Street Sub-Station

This type of relay will act as a selecting relay in the reverse direction, operating at lower load and within less time, provided the voltage is above 40 per cent. of normal.

The switch panels controlling the secondary side of the transformers are provided with a power factor indicator, a voltmeter, a graphic recording wattmeter, a synchronizing lamp (which operates in multiple with the synchroscope), and an ammeter in each of the three legs of the circuit. A diagram of the main connections is shown in Fig. 10. It will be noted from this diagram that the incoming 60 cycle feeders may be operated independently of the others on their own set of transformers, feeding into either of the buses on the secondary side. On the high tension side there is also a short cross-connecting bus, permitting any feeder to operate any of the transformer sets, if necessary; or, all feeders may be closed in multiple through this bus. A somewhat similar arrangement is shown for the 25 cycle feeders. While there are two general station buses, it is usual to operate on No. 1, as the induction feeder regulators are connected to this bus. It is possible, however, to operate the feeder from the No. 2 bus, without the induction regulator, thus permitting the regulator and all current and potential transformers to be removed for cleaning or repairing. Of course, when the feeder is on No. 2 bus, there is no means of regulation between the bus and the feeder; but in this contingency a motor generator is started to supply No. 2 bus and this particular feeder, the generator being regulated to suit the voltage demands of the circuit. As a matter of fact, however, for a considerable time each day the drop in the feeders with light load is so small that if the primary voltage at Waterside is adjusted to the right point to give the proper sub-station bus voltage, a number of feeders may be operated directly from the bus without the use of regulators. The momentary fluctuating load on any one feeder is not sufficient to require adjustment to compensate for it.

The feeder panels are provided with one ammeter (which is in one of the outside legs of the circuit), a voltmeter, and the usual type of overload and inverse time element relay. I might repeat here that each feeder supplies its own particular district and is not in multiple with any of the adjacent feeders, either on the 3000 volt distributing side or the secondary network fed from transformers on the consumer's premises. This means that the voltage of each feeder is regulated to maintain constant voltage on the distributors, the layout of the distributors being such that there will be the minimum voltage drop between the feeder terminal and any point on the distributors. This reduces the question of feeder regulation to that of maintaining constant voltage at the center of distribution. For some time this was done by means of a voltage chart which showed the necessary additional voltage to compensate for feeder losses at various ampere loads. Feeder compensators were later installed, and after proper adjustment were found to work very satisfactorily for this purpose, reducing the work of the operators to that of simply maintaining constant voltage indication on each feeder. The induction regulators are motor operated, and are controlled by means of a small drum switch mounted on the control panel. To carry this method to its logical conclusion, which means instantaneous control of the regulator when any control is necessary, and to relieve the operator of this work, which at best can result in but an approximation, the Company has been experimenting for some time with various methods of automatic regulation. The principle on which these experiments are based is to operate a contact-making voltmeter from the compensator, the contact voltmeter in turn controlling the induction regulator. Quite satisfactory results have been obtained from this method.

It might be proper, at this point, to describe some of the troubles experienced with this system of distribution and the methods of locating them. It may be admitted at the start, that if a feeder or any large distributor connected to it is short-circuited, the feeder and its district is out of service for the time being. However, short circuits of this kind are rare, and it is often found that when trouble comes on a feeder, it may still be operated by opening the power leg only. This operation, of course, discontinues the power service; and if for any reason it is found inexpedient to do this, there are a number of small oil switches in various parts of the district which may be operated, permitting parts of the distributors to be disconnected, or, if necessary, switched over onto the distributors of the adjacent district.

The next question that arises is, how is the fault to be traced to the faulty section of the feeder district? Where only a ground shows up on one of the legs of the feeder, the feeder is continued in operation, but is transferred to the spare bus and operated from a separate motor generator or set of transformers. In any case, however, whether it is but a single ground, or trouble of a more serious nature, the same method and apparatus are employed to locate it. The detection and location of grounds on the system involves four operations, namely:

(1) Indication of ground.

(2) Determination at switchboard of grounded feeder.

(3) Impressing high frequency current on grounded feeder.

(4) Tracing feeder to the location of feeder ground.

For locating a ground on the system, the apparatus is arranged as shown in Fig. 11. Connection is made from one side of a 220 volt exciter bus, through three 110 volt lamps, a 150 ohm telegraph relay, and a non-inductive resistance of 10,000 ohms, to one of the middle points of a double-pole double-throw switch. This switch is normally in the upper position, the circuit being completed through three additional 110 volt lamps to the other side of the exciter bus. The three lamps last referred to are also connected between the one side of the exciter bus and the ground by a fixed ground lead. From a point between the first three lamps mentioned and the relay, a tap is taken to the other upper pole of the double-pole double-throw switch. From the corresponding center point of this switch, the circuit is carried through a 440 ohm inductive resistance to a flexible lead which may be connected by means of an insulated handle to any one of the three station buses. While the resistance in this circuit is only 440 ohms, it has an impedance, at 60 cycles, of about 620,000 ohms. The purpose of the inductive resistance is to prevent the high voltage current of the 3000 volt bus finding its way to ground through the testing apparatus.

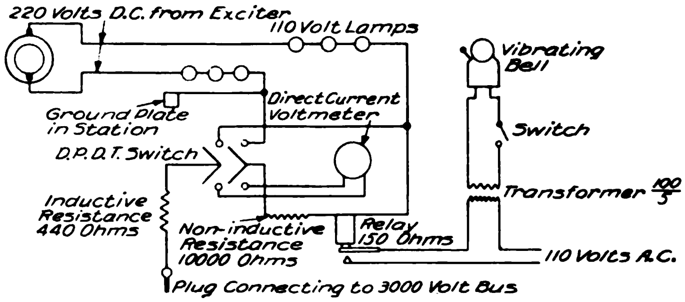
220 Volts D.C. from Exciter
110 Volt Lamps
Vibrating Bell
Ground Plate in Station
Direct Current Voltmeter
Switch
D.P.D.T. Switch
Transformer $\frac{100}{3}$
Inductive Resistance 440 Ohms
Non-inductive Resistance 10000 Ohms
Relay 150 Ohms
110 Volts A.C.
Plug Connecting to 3000 Volt Bus

Fig. 11. Apparatus and Connections for Indicating Grounds

With the double-pole switch in the upper position as described, and with no ground on the system, the telegraph relay is energized by current flowing through it from one exciter bus to the other. The contacts of this relay are in series with a 110 volt A.C. circuit, and when closed, energize a transformer having a ratio of 100 to 3, supplying the alarm bell at about 3 volts A.C. In the normal position, with no ground on the system, the relay contacts in the bell circuit are open. When, however, a feeder or any other portion of the high voltage system becomes grounded, the exciter current, instead of passing through the high resistance path of the relay and the 10,000 ohms resistance, by-passes through the 440 ohm inductive resistance to the station bus, thence over the grounded circuit to the ground, and returns through the station ground lead. The relay being thus short-circuited, the armature drops, closing the primary of the low voltage transformer, and the alarm bell rings.

A ground on the system having been indicated and the grounded feeder located, the next operation is to find out which phase is grounded. This is done by means of a small transformer, one terminal of the primary of which is connected to any one of the three buses, the other terminal being grounded. A lamp is connected in series with the secondary. If the lamp lights, the indication is that that leg is not the grounded one. The transformer terminal is then shifted until a bus is found which does not light the lamp, this bus being the grounded leg of the feeder.

A high frequency current is next impressed on the grounded leg, this proceeding being necessary because of the particular method employed for locating a ground. For this purpose, what is virtually a transformer is placed over the grounded cable, a telephone receiver being connected to the transformer terminals. I might say here that in some cases of heavy ground it is not necessary to actually place the transformer on the cable, since by simply hanging it in the manhole, a clearly defined note is produced in the telephone. On any cable of the system, a low hum is heard due to the 60 cycle current. When a cable is grounded, however, and the high frequency current impressed on it, a distinctly higher note is heard in the receiver, on any section of that particular cable between the station and the ground. To further emphasize the difference in the tone and make it more distinguishable, the high frequency current is shunted alternately through a bank of lamps and the grounded cable, several times a minute. This method gives an intermittent high frequency hum in the telephone, which is easily distinguishable from the lower and constant note of the system.

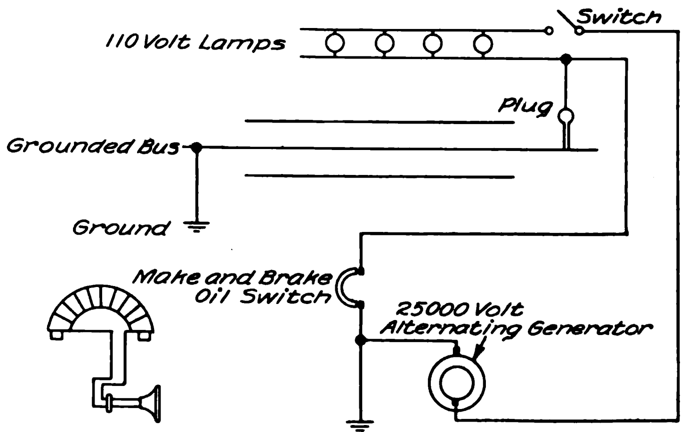

Fig. 12. High Frequency Apparatus for Locating Grounds

The high frequency apparatus and connections are shown diagrammatically in Fig. 12. The generator is of 1 h.p. output, and supplies 110 volt current at 25,000 alternations per minute. One terminal of the generator is connected to a grounded wire and the other to one side of a bank of 110 volt lamps in multiple. By increasing or decreasing the number of lamps connected, the amount of the high frequency current in the circuit may be varied; thus, the intensity of the note in the receiver may be increased if, because of the high resistance of the fault, it is too low. The number of lamps may be varied from 3 to 15 or more, but a low resistance ground has been located by the current from one lamp. It will be noted that the make and break oil switch is in shunt with the feeder and ground return, so that when this switch is closed the lamp bank is lit to full brilliancy, the current being shunted from the ground circuit. Under these conditions, the current flowing through the cable to ground is so small as not to be detected by the telephone. However, when the switch opens, the defective feeder and ground return are in series with the lamp bank, giving the high frequency note in the telephone detector. This shunting switch is driven by a small fan motor at the rate of about 12 make and breaks per minute. The reason for shunting the defective feeder and ground return, rather than opening the circuit through it, is that it was found that the current could be reduced to a very small fraction by shunting, still maintaining the circuit through the break; but if the circuit is opened entirely, it is liable not to re-establish itself. At first sight, it appears peculiar that there should be any difference in a circuit of this character, whether the current is reduced to an infinitesimal amount by shunting it, or reduced to zero by actually opening it; but practice has confirmed this view, and shown that there is an important difference obtained in the maintenance of continuity through the fault.

The small transformer and telephone receiver are also shown in Fig. 12. A standard telephone receiver is used. The transformer is of ordinary transformer iron, 2½ in. wide, built up to ½ in. thick, and of such length that when bent and wound with the coils, it can be passed over a ½ in. cable. The transformer is wound with about one pound of No. 25 silk covered wire, and connected to the telephone by 15 feet of flexible conductor.

The addition of a direct current voltmeter (Fig. 11) to the arrangement already described permits of a further important use of this equipment. I refer to the ease with which resistance to ground may be measured, whether it be that of the system as a whole, a separate feeder, or any part of the station equipment. By simply throwing the double-pole switch to the lower position, thus cutting the direct current voltmeter in circuit, the deflections may be used in the following well-known way to determine the insulation resistance.

$$R = r\frac{v^1 - V}{v^1}$$

where

R = Insulation resistance.
r = Resistance in voltmeter circuit.
v^1 = Deflection of voltmeter to ground.
v = Deflection of voltmeter to circuit.

The deflection v is obtained when the terminal in the lower left-hand corner is connected to the bus or other part of the system to be measured. The deflection v^1 is obtained by making contact with the ground terminals. In the equipment in use, the resistance r is 28,700 ohms, resulting in a value for v^1 of about 140; and with the insulation of the whole system normal, the deflection v is about 20, thus showing a system insulation of 175,000 ohms. It is understood, of course, that insulation measurements are usually made on the live system; it is, in fact, routine practice to make a system measurement during each watch of eight hours, to be noted in the station reports. In this way any considerable reduction in the insulation resistance will be noted, and each separate feeder, generator or transformer set will then be tested separately on an independent bus; thus, the section on which a fault has developed will be located, and the proper means immediately employed to have it remedied.

It is also routine practice to separate each of the 25 and 60 cycle high tension feeders, and the 3000 volt feeders, once a week for individual insulation measurement. This tends to the earlier location of incipient faults, which might otherwise develop into more serious trouble.

We now come to the underground distributing end of the system.

The Subway Companies prohibit the use of subway transformers in New York city. Therefore, all distributing transformer installations must be made within the curb line, and on property controlled by the consumer. This brings the whole installation within the jurisdiction of the Fire Underwriters' rules, which prohibit the use of oil in transformers; consequently, all the transformers for general distributing work are air-cooled. The transformer in general use by this Company, after having gone through a rather rigid evolutionary process, resolved itself into the shell type, the coil ends being protected by a lattice casting with feet, on which the transformer rests. All transformers are placed in a horizontal position on the floor, or on some suitable support, but are never bolted to a side wall. The transformers range in size from 2 to 25 kw., the majority, however, being between 10 and 25 kw.; in fact, there are more 25 kw. units than all other sizes combined. Transformers within this range have the same regulation; namely, 1.3 per cent. at 100 per cent. power factor, and are of such characteristics that they may be used in multiple in an installation to make up whatever aggregate capacity may be required.

On December 31, 1907, there were 1356 transformers of all sizes on the system for lighting, and 421 for power, or a total of 1777, with an aggregate capacity of 30,491 kw. While this may seem a rather large number of units, it must be kept clearly in mind that the conditions under which transformers are installed on Manhattan Island are unusually severe. This is a result of the the following conditions: The distribution system is entirely underground, making it necessary to place transformers either in manholes or on private property; but no manhole transformers are permitted, as already stated, thus making installations on private property the only ones possible. Other factors affecting the installation of transformers are: The capacity which can be installed in a certain location; the ventilation of the transformers in this location; and the limited space of access. The last of these is a restriction frequently met with; in fact, it is because of this limitation of what may be called the "area of access," together with the weight of single parts which may be handled through such passages, that it was found impracticable to use transformers larger than 25 kw. While a great many installations have an aggregate capacity greater than 25 kw., they have to be made up of collections of units limited to this size, or smaller in some cases, resulting in the low average size of transformers on the system as a whole. From this it may be inferred that the iron losses per year are abnormal; they are, in fact, between 9 and 10 per cent. of the total kw. generated. But it should be kept in mind that the extremely low average feeder loss from the sub-station bus to the transformers, with a relatively low investment for this system, together with the fact that the whole Island of Manhattan is economically covered by but two sub-stations (reducing fixed and operating expense per kilowatt output), largely offsets the iron losses, and results in a fairly good distributing efficiency between Waterside bus and consumer.

While some transformer installations are made for the sole purpose of supplying a particular consumer, it is the general practice to connect the transformer secondaries to feed back into a secondary network. Therefore, when a favorable transformer location is secured, it is usual to install the maximum transformer capacity, the surplus being fed back into the secondary network. This method very materially reduces the number of separate transformer installations necessary to handle a given number of consumers in a district that has a reasonably dense business. There is also an incidental advantage to the consumer on whose premises transformers are located, in that if his transformers become defective, his service is not necessarily interrupted, as the defective transformers will clear themselves on both the primary and secondary sides, thus leaving the consumer supplied entirely from the secondary network to which adjacent installations are connected. It is due to this consideration, as well as to the broader one, that when installations of this character are necessary on the consumer's premises as an accompaniment to its service, the Company is justified in its exclusive occupation of this portion of the premises. This point is covered by the following clause in our contract with the consumer:

> "It is further understood and agreed that, during the term of this contract, suitable and sufficient space shall be provided (not exceeding approximately 3 ft. x 6 ft. floor space) without rental charge, for such service and converting apparatus as the supply company may consider necessary."

It is usually coincident with the larger consumers' installations that the most favorable locations for the transformers are found. Rental is therefore seldom paid for the space occupied. It is sometimes the case, however, that a particularly desirable location for transformers is to be found on the property of a relatively small consumer. In such cases it is usual to occupy the space on a rental basis, because the bulk of the transformer capacity is utilized on the network. No device, automatic or otherwise, is used to disconnect the primaries of the transformers during light load, as this appears impracticable from several points of view, among which is the unexpected demand on the secondary network that may be made during light load hours because of thunder showers, or because of the particular business supplied. Also, in case of short circuit on the secondary mains during light load hours, there might not be sufficient transformer capacity in operation to burn off and clear the short circuit.

The lighting network itself is laid out for 3-wire service, with 110 volts between center and outer conductors. The 3-wire mains are of single conductor lead-covered cable, the three conductors being generally drawn into the same standard subway duct. All street secondaries are tied together at every junction, providing a generally interconnected network.

While the distributing network has been for some years on the 3-wire basis, this was not the original practice, because of the patent situation. The former system was of 2 wires, at 220 volts. When a 3-wire consumer was secured, either as an original installation or in competition with the Edison 3-wire system, he was supplied on the 3-wire plan by using an auto-transformer with a middle tap. The transformer was located on the premises. This scheme did not conflict with any of the 3-wire patents, and at the same time secured the advantage of that method of distribution with only the slight disadvantage of the auto-transformer.

As previously explained, the lighting transformers are all connected across 3000 volt single-phase primaries. On the secondary side, a tap from the middle of the 200 volt secondary supplies the neutral. For the few 2-wire secondaries that are still in use, the transformer secondaries are connected in multiple in the usual way.

For 3-wire 2-phase power supply, two standard transformers are connected in the manner previously shown; *i. e.*, one transformer across the 3000 volt outer conductors, with its primaries in series, the other transformer connected to the middle conductor and the center of the first transformer, with its primaries in multiple. It is the usual practice to install a set of transformers wherever any considerable power is required. These power installations, however, are used to feed back into a 2-phase, 200 volt, 3-wire power secondary. In this way the lighting and power secondary systems are kept separate and distinct, and the lighting system is only remotely affected by intermittent power demands, such as elevators. All variations on the power secondary and the transformers supplying it have no influence on the lighting secondary, which can be affected only by variations sufficiently great to cause a noticeable change in the primary voltage.

The 3-wire secondaries are usually made up of three separate single conductor lead-covered cables drawn into the same subway duct similar to the lighting secondaries. In some congested sections of the subway system, the small primary distributors have been drawn into the same duct with the secondaries, and no trouble has been experienced from this practice. Of course, the neutrals of both lighting and power secondaries are grounded.

Power for all classes of commercial uses is being supplied, including a large number of passenger elevators. The question of supplying passenger elevators from the same mains as the lighting system has been given particular attention by the Company, and has involved, at times, some experimental work.

In this connection, I wish to quote in part from a paper prepared by Mr. W. E. McCoy, Electrical Engineer of the United Electric Light and Power Company, entitled, "Some Notes on the Operation of Alternating Current Elevators," and read at the 1907 meeting of the Association of Edison Illuminating Companies:

"Many are in doubt as to whether elevators of this type can be successfully operated from the same mains as the lighting without affecting the lighting when the motor is started. The United Electric Light and Power Company has somewhat more than 420 elevators connected to its lines, all operated by 2-phase induction motors. The rotors are the 'squirrel-cage' type, and the motor is thrown directly on the line by a simple double-throw switch, no control devices of any kind being used. It is the practice of some of the lighting companies to express their motor specifications in terms of starting current, but it may not be wise under all circumstances. The United Electric Light and Power Company limits itself to the general specification that the motor must be designed for the work it is intended to do." In other words, it must represent the best practice in motor design for which the particular class of motor is intended.

"A rotor with high resistance short-circuiting rings will have a lower starting current and a higher starting torque, but will operate at lower efficiency; or, one may be designed with higher efficiency and it will have lower starting current, but it will also have a lower power factor. The starting current can be limited in two other ways, both of which, however, are to the disadvantage of the consumer: One is to use auto-transformers connected in the primary for varying the voltage applied to the motor, the other is to use a variable resistance in the secondary—but this means collector rings and brushes.

"A low starting current will not always be obtained with an auto-transformer, even if the controller is moved step by step, for the reason that when the car is heavily loaded the motor may not start until the controller has about reached the last step, when the full voltage is thrown on, causing as high a starting current as though no controller had been used." This means that from the time the first contact is made, to the later one when the motor begins to move, there is a consumption of energy without any work being performed.

"However, any device made to limit the starting current will increase the consumer's bills."

In view of this fact, it was necessary for the Company to undertake considerable experimental work to determine the power required for operating motors with several types of controllers. It had to consider first the question of service distribution, and then determine to what extent it could permit the use of motor designs which favored the customer at the expense of the Company. The truth of the paradoxical statement just made can be proven by reference to Fig. 13.

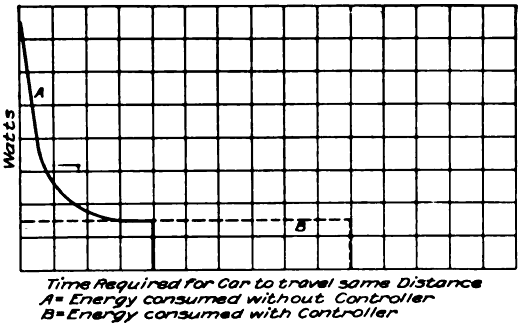

Fig. 13. Time-energy Curves of Elevator Motor Operated With and Without Controller

Quoting further from Mr. McCoy's paper: "Suppose for a moment that the motor, when started without a controller, takes five times the energy that it would when running; suppose also that the same motor is started with a controller having a sufficient number of points so that at no time will the energy be greater than that taken when running. Without the controller, the motor will accelerate at a higher rate, and, of course, run the car to the limit point in a shorter time than with it. The energy registered on the consumer's meter, in each case, can be seen by referring to Fig. 13, and comparing the areas of curves A and B."

While energy consumption is one of the things of primary concern to the consumer, it is also of importance to the Company, because, in the last analysis, any legitimate reduction in the power consumption for a given service must result favorably to the Company.

The cost of operating the earlier A.C. equipments was very much higher than that for direct current. On the later equipments, however, this does not hold good. In fact, a number of consumers have undertaken the expense of changing from the earlier to the later type of A.C. apparatus, resulting, in some cases, in a reduction in their bills of as much as 40 per cent. and, at the same time, eliminating the noise inevitable with the earlier types.

In connection with this question of noise, most of us are familiar with that made by the induction motor, particularly when being started. This was one of the serious practical questions that had to be met, and while considerable work was carried on by the Company with this end in view, it seemed, for a long time, almost hopeless to get a motor that would start and run quietly. This, however, was accomplished a little over two years ago by the simple expedient of spiraling the rotor, which, with other factors in the design, resulted in a practically noiseless motor, both under starting and running conditions.

Quoting still further from Mr. McCoy's paper: "Some of the results obtained by the Company in their tests are summarized in kilowatts per car mile on the following diagram. (Fig. 14.) These results were obtained with an equipment installed by the Company for the particular purpose of testing various types of motors under exactly the same conditions as to speed, weight on car, number of stops, etc. While the actual kilowatts per car mile are rather high, that is explained by the fact that the car was not counter-weighted, although this would not affect the relative results.

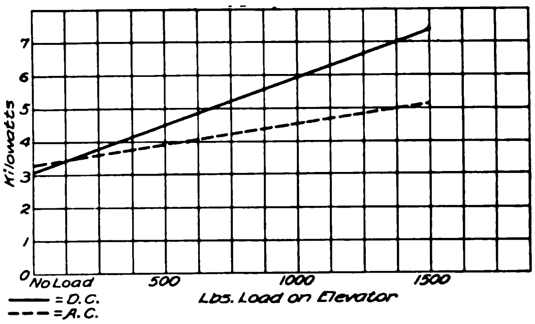

Fig. 14. Kilowatts per Car Mile for A.C. and D.C. Motors Operated Under Same Conditions

"It will be seen that at the heavier loads the kilowatt hours per mile on the direct current outfit are higher than on the alternating current equipment, due, no doubt, to rheostatic losses. The curves show that if an elevator is installed where it will operate on light loads of less than 10 per cent. of its capacity, the bills for current will be slightly lower for the direct current machine; also, if operated on heavier loads, covering the upper 90 per cent. of its capacity range, the alternating current elevator is the cheaper to operate."

It is these considerations that have placed the alternating current motor for apartment house service, freight elevators and similar classes of service, in a competitive position with the direct current equipments.

"Another important point that has favorably impressed users of A.C. elevators, is the low cost of maintenance due to the absence of any controlling device, rheostats, commutators, or collector rings. From this consequent simplicity, most of our consumers very soon found that it did not pay to make maintenance contracts; in fact, some of the very first installations are still operating without having had any material repairs other than the re-babbitting of the motor bearings. Most manufacturers now make no distinction in price, whether an A.C. or D.C. motor is required with the elevator equipment."

From the foregoing, I do not wish to be understood as advocating the indiscriminate placing of these equipments on a thin distributing system, as the problem finally resolves itself into the relation between the stability, or "ballast" of the distributing network, and the maximum simultaneous demand of any probable combination of units.

As illustrating one of the special classes of consumers supplied by the United Electric Light and Power Company, I will mention some of the principal features of the local installation on the property of the National Biscuit Company, which is the largest industrial consumer in New York city.

In this installation there is a total of 174 motors, aggregating 1342 h.p., and ranging in size from ⅛ to 150 h.p. They also have over 7000 incandescent lamps. An installation, made up of six 200 kw., 7500 volt to 220 volt oil-cooled static transformers, connected 3-phase to 2-phase and aggregating 1200 kw. continuous capacity, is for the purpose of supplying light and power to their large factory. These transformers are supplied by two high tension feeders direct from the 60 cycle bus at Waterside. All switches and buses are installed in concrete compartments. The switching arrangement provides for the isolation of any transformer or either feeder without interrupting the service.

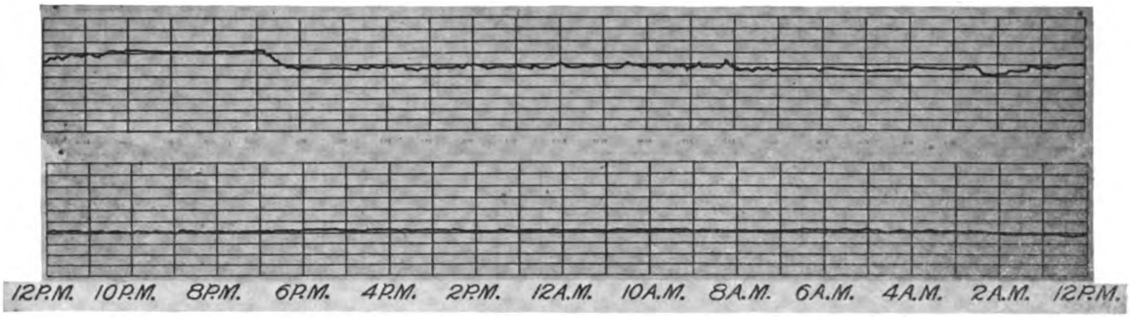

Fig. 15. Upper Curve, Voltage of Waterside Bus; Lower Curve, Voltage as Regulated for Service to National Biscuit Co.

As this installation is served direct from Waterside bus, which has a considerable voltage variation during the 24 hours, it was necessary to include potential regulators. These regulators operate on the primary side of the transformers, and have a capacity sufficient to compensate for voltage changes of 10 per cent. either side of normal. There is one regulator for each of the two secondary phases. The regulators are oil-cooled and motor operated, the motor being controlled by an automatic contact-making voltmeter and relays.

That a regulator is absolutely necessary to compensate for the periodic changes at Waterside, a typical chart of both Waterside bus and the regulated service to the National Biscuit Company is shown, both charts being for the 24 hours of April 6th last. (Fig. 15.)

As an example of some of the special work with which the Company has recently interested itself, I might mention the modification of the standard mercury arc rectifier, adapting it especially to the use of moving-picture machines. While a choke coil or constant current transformer may be used to operate the arc lamp without rheostatic losses, there still remains the principal objection to alternating current for this purpose, which is, that the frequency now and then coincides with the rate of change of the picture films, thus showing blanks and creating an annoying flicker. Tests also show that for equal curtain illumination, 18 to 20 amperes direct current are equivalent to 30 amperes A.C., both at the same voltage. However, any rectifier or other devices used on the A.C. circuit for picture machines must be absolutely automatic, and independent of any attention on the part of the operator; in fact, it must be the operating equivalent of a direct current supply. These conditions have recently been met by simplifying the standard rectifier equipment, and by some modifications in the design, the arc lamp may be connected directly to the terminals of the rectifier without a rheostat. When the lamp terminals are closed, the rectifier starts automatically, and also automatically limits the current through the short-circuited lamp to a safe margin. Taking into account the loss in the rectifier itself, and allowing for the cost of tubes, tests have demonstrated that, because of the elimination of rheostatic losses, the average user of picture machines can employ a rectifier equipment and save enough in cost of current, at standard rates, to pay for his equipment in about a year, at the same time securing the advantage of direct current at the arc, supplied at exactly the potential required. The use of alternating current in combination with the rectifier for this class of work shows distinct advantages over direct current supply, due to the elimination of rheostatic losses in reducing the voltage from 115 to 50 volts.

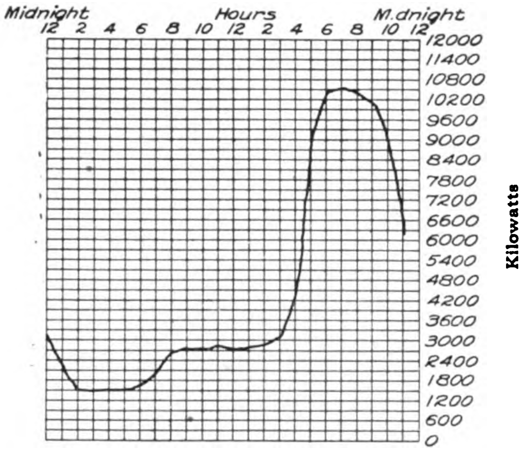

Fig. 16. Typical 24 Hour Load Curve on Generating Station

Referring to the Company's system in general, it has already been stated that it covers practically the whole of Manhattan Island, from the Battery to the Harlem River. It has a maximum load of between 11,000 and 12,000 kw. The system has a connected load of about 661,000 16 c.p. lamps. The Company has service on 146½ miles of streets, and occupies 287 miles of subway duct.

Fig. 16 shows a typical 24 hour load curve of the system. While the power load is relatively small, the load factor for this particular day was 40 per cent.

The total operating efficiency of the system for 1907 was 76.2 per cent., taking into consideration all current unaccounted for, including transformer losses, unmetered and stolen current. More than 14,000 meters are in use. The equipment of the meter testing department includes the usual apparatus for this purpose, such as laboratory standards for checking the rotating standards which are used for general testing. After a meter has been repaired, it is given the usual tests, but to make sure that it is correct as to power factor and creeping, it is put on 150 per cent. potential for a creeping test. For power factor test, the current and potential circuits are put on opposite phases of the 2-phase system, in series with a rotating standard that is known to be correct on power factor. As the relation between the two phases of our system varies to some extent, a small hand-operated induction regulator is used to balance the potential, which is adjusted until the rotating standard is at rest. If the repaired meter is also at standstill under these conditions it is passed as "O. K."

On the question of general meter efficiency of the system as a whole, the tests made by the meter department for the year 1907, may be summed up as follows:

Taking all the meters of the system, including the complaint meters, periodic and special tests, 98.93 per cent. were found to be within the legal limits of accuracy on a $\frac{1}{10}$ load, and 98.75 per cent. on full load. These figures might be termed, from the standpoint of the public, "The Commercial Metering Efficiency" of our system.

THE RISE AND PROGRESS OF ELECTRICAL SCIENCE*

By W. S. Andrews

The purpose of this paper is to present a brief historical sketch of the rise and progress of electrical science, chiefly in connection with its application to the production of light.

Experimental development along this line may be said to have had its starting point during the middle of the seventeenth century, for previous to that time all knowledge of electrical phenomena was confined to experiments with amber and the lodestone.

If we may believe the legends of the Chinese, a knowledge of the north and south directive tendency of the lodestone dates back to remote antiquity. The ancients were also well acquainted with the fact that by rubbing amber with a dry cloth it could be made to attract small feathers and similar light bodies. These qualities of amber and the lodestone were attributed to so-called peculiar and individual "virtues" which either resided naturally and independently in the substance, as in the lodestone, or could be temporarily communicated, as by the rubbing of amber.

Until the middle of the fifteenth century, the attractive properties of amber and the lodestone were supposed to be identical in their origin, and were commonly attributed to magical or occult influences. About that time, however, men's minds began to awaken with a spirit of inquiry. Slowly and laboriously new facts were discovered, compared, and classified, so that by the middle of the sixteenth century the qualities of amber and the lodestone were clearly differentiated and stripped of their supposed mystical origin. Science thus gaining one of her earliest victories over ignorance and superstition.

From that time on, advancement was more rapid. The close of the sixteenth century was illumined by the immortal genius of Gilbert, whose discoveries in magnetism, as recorded in his writings, constitute the genesis of the science to which he was the first to apply the term "Electrics."

Following Gilbert may be mentioned Otto Von Guercke, who invented the air pump and also produced the first machine that was ever built for the purpose of generating electricity.

This machine consisted of a sulphur globe having an iron axis by which it could be turned while friction was applied by the hand to its surface. It was primarily intended for investigating the attraction and repulsion of light bodies, but later on Von Guercke discovered that his machine gave forth crackling sparks and brushes of fire, which were plainly visible when it was operated in a dark room. This is believed to be the earliest observation of an "electric light," and was made by Von Guercke about 250 years ago. He thus inaugurated the experimental stage in the production of light by electricity.

Dr. William Gilbert
From the Clamp Engraving made in 1796 from the Original Portrait

The earliest record of an electrically lighted vacuum tube is the one that was made at the Royal Observatory of Paris a few years later by Jean Piquard, who was known as one of the most eminent astronomers and scientists of his time. In Piquard's notes, dated 1675, he relates that while carrying a barometer from one room to another in the observatory, he noticed a curious flickering light in the upper part of the tube over the mercury. This strange phenomenon excited much curiosity, but the wise men speculated at random as to its origin.

At about that time a German chemist, named Brandt, discovered a method for extracting a very crude kind of phosphorus from bones and other animal matter, and it was supposed by Bernoulli and some of his contemporaries that there might be a connection between the light given off by this substance when rubbed in the dark and the glow in the barometer tube; so the latter was some times called the "Mercurial Phosphorûs." Bernoulli very materially improved upon Piquard's discovery and showed that luminous effects could be produced by simply shaking mercury in a dry bottle, and this experiment created extravagant ideas of a new illuminant calculated to supersede the then existing methods of artificial lighting, which were naturally not very brilliant.

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* Paper read before Schenectady Section A.I.E.E.

Dr. Benjamin Franklin
From an Old Engraving by Fisher from the Mason Chamberlin portrait

In 1705, Hawsbee became interested in these discoveries and applied himself diligently to further investigation. He improved very much on Von Guercke's electric machine, using a glass globe instead of one made of sulphur, and demonstrated that the mercurial glow was of electrical origin and therefore similar to the light produced by friction in the revolving glass globe of his electrical machine. Proceeding further, he made an improved form of air pump which enabled him to exhaust glass bulbs to a higher degree than was previously possible. By bringing one of his exhausted bulbs near to the revolving globe of the electrical machine he found that it became luminous without having any actual contact with the exciting apparatus. He was thus the first in the field to demonstrate the inductive effect of electricity.

Space will not permit an enumeration of the many noteworthy experimentalists who continued to enlarge the sphere of the new science, but brief mention may be made of the patient and ingenious investigator, Stephen Gray, who, in his humble room in London, with the crudest appliances, gave science the first ideas of the insulation and transmission of electricity. His electric generator was a glass rod, which he rubbed with a dry cloth, and his conducting line was a damp string suspended on dry silk threads for the purpose of retaining the electric charge. By such simple contrivances he was enabled to transmit the electric "virtue," as he called it, for hundreds of feet in the open air. This occurred in 1730, and Dufay, the brilliant French scientist, hearing of Gray's experiments, was fascinated by their originality and the possibilities which they suggested, so he repeated them and also improved on Gray's ideas by using glass tubes and lumps of wax instead of silk threads for insulating his conductors. By these means he was able to construct more substantial and longer lines, but he still used damp strings for conductors, for, strange to say, the idea of using metal wires does not appear to have been thought of until long after this time. Dufay was thus the first to devise rigid insulators, and in his notes written in 1733 may be found the word "insulated" as first used in reference to an electric conductor.

One of Dufay's most important discoveries was that particles electrified by glass repelled each other, but were attracted by particles that were electrified by resins, although the latter particles also repelled each other; thus demonstrating the law that similar charges repel each other but attract opposite charges. This discovery led him to believe that there were two kinds of electricity which he termed respectively "vitreous" and "resinous."

A sentence written by this illustrious investigator in his last memoirs in 1737 is worthy of quotation.

"Electricity," he wrote, "is a quality universally expanded in all matter we know, and which influences the mechanism of the universe far more than we think."

Scientists now began to vie with each other in the production of larger and more powerful machines; they also learned to connect them in multiple to intensify the discharge. The general public also caught up the new craze, and the manufacture of electrical machines and apparatus became a profitable industry.

Passing on rapidly, attention may be called to Von Kliest's attempts, in 1745, to bottle up electricity, resulting in the discovery of the famous "Leyden Jar," the noisy discharge of which was likened, by the brilliant Nollet, to thunder and lightning; but it remained for the penetrating intelligence of the immortal Franklin to demonstrate the absolute identity of these phenomena by his world renowned and well-known kite experiment which he made in Philadelphia in the year of 1752.

We will now bid farewell to the old-fashioned frictional electric machines and conducting lines of damp string. These things were but toys, but they served a good purpose in their time and prepared the way for broader and more important work.

The last year of the eighteenth century witnessed the advent of a new era in electrical development, for in March of that year Alexander Volta made public his invention of the electric pile or battery, and this comparatively powerful source of electricity opened a wide path into fresh fields of discovery.

In 1810, Humphrey Davy, with a battery of 2000 pairs of copper and zinc plates amazed the world with the first arc light, which he produced between charcoal points at the Royal Institution in London. The soft and friable character of the charcoal, and the absence of all regulating devices naturally resulted in a very flickering and uncertain light, which was totally unfit for purposes of public illumination. It is a curious fact that no further improvements were effected for many years thereafter, and this first arc light remained only a brilliant laboratory experiment until 1844, when Foucault, using Bunsen batteries and electrodes of hard gas carbon, succeeded in making a comparatively steady arc, the value of which was at once appreciated. With even this improvement, however, the light fell far short of the practical requirements of a useful illuminant, for the primary battery, by reason of its expense, inconvenience and short life, was incapable of giving satisfactory electrical service. Modern electrical science is therefore primarily indebted to that ardent experimentalist and profound student of science, Michael Faraday, for his grand conception of magnetic induction in the year 1831, which alone has made possible the development of our existing electric lighting and power systems.

Davy was one of the first to discover and recognize the value of the electric arc, not only as a source of light, but also as a means for producing intense heat, and he left a record of his experiments in this connection. "Platinum," he says, "was melted as readily as wax in the flame of a common candle; quartz, the sapphire, magnesia, lime, all entered into fusion."

As in the case of the electric arc light, however, for lack of an economical and abundant source of electricity, this valuable heat property of the electric arc remained in abeyance for many years, until in the early 80's of the last century the introduction of the dynamo electric machine enabled Sir William Siemens to construct and use the first practical electric arc furnace, the fruits of which are manifest to-day in the wonderful development of the modern science of electro-chemistry.

It would be tedious to follow in detail the many advances which marked the first half of the nineteenth century. Mention must, however, be made of Oersted's discovery in 1819, of the deflection of the magnetic needle by the electric current; of Ampere, who soon afterwards elucidated the theory which explained this phenomenon; and of Ohm, who formulated the electrical law which has immortalized his name.

In 1826 Joseph Henry, a native of Albany, N. Y., commenced his original and classical investigations in electricity and magnetism, which were particularly notable because so little had been done along these lines in this country since the days of Franklin. In 1829 Union College conferred upon him a degree for his distinguished contributions to science. In his later years he was honored by the appointment to draw up the plans and supervise the general layout of the Smithsonian

Institute in Washington, D. C., and his statue on the grounds near that building commemorates his untiring zeal in the work that was intrusted to him, and constitutes a fitting tribute to his memory.

As before stated, Faraday discovered and published the principle of magnetic induction in 1831, but he left to others the task of working out its practical applications, being himself devoted to the investigation of pure science. His wonderful discovery, however, soon began to bear fruit in the shape of many different forms of magneto-electric machines which were brought out by different inventors.

Menlo Park in the Early 80's

First among these inventors was Pixii, who exhibited his magneto machine in Paris in 1832. He was followed by Saxton in 1833, and Clark in 1834, with many others who successively developed some improvements in their different models. In all these machines, however, permanent steel magnets were used to excite the revolving armatures, but in 1842, Elias of Amsterdam constructed a remarkable and entirely novel apparatus in which electro-magnets were employed throughout, and which, although designed to work with a battery as an electric motor, and only used as such, really embodied some of the essential elements of the modern multipolar generator.

The time, however, was not ripe for such a startling innovation as this, so it attracted but little attention, and the general run of inventive thought continued to follow in the well-worn grooves of magnetic induction for many years thereafter.

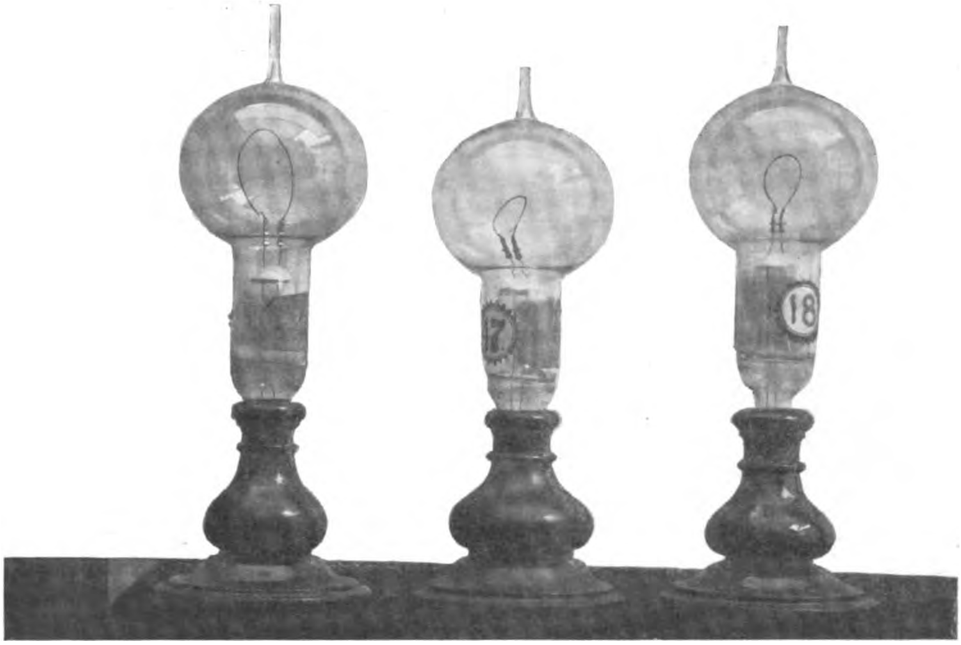
The first English patent on an arc lamp was issued to Stark in 1836, but this lamp was crude and unsuccessful. Serrins, however, patented an arc lamp in 1857 which possessed considerable merit, and succeeding inventors contributed further improvements.

Comparatively large magneto-electric machines were now built, and one of these generators, designed by Holmes, was installed and used in connection with a Serrins arc lamp to illuminate the lantern of Dungeness Lighthouse in 1862. This was the first practical and permanent application of the electric arc light to this beneficent purpose.

The self-exciting principle of the direct current generator is said to have been discovered almost simultaneously by Wheatstone, Siemens and Varley, but the first machine in which the principle was demonstrated was made by Wheatstone in 1866, and was the forerunner of our modern types of continuous current generators.

In 1870 Gramme invented the method of armature winding which bears his name, and in 1872 comparatively large Gramme machines were built and used for various commercial purposes. In 1873 the Clock Tower of the House of Parliament in London was illumined for several months by arc lights supplied with current from one of these generators, and similar machines of this type were also employed a few years for illuminating purposes in the English and other European navies, but the large first cost of these lighting plants, together with their heavy running expenses, militated against their commercial use to any great extent.

In the meantime a general interest in electric lighting was being rapidly awakened in this country, and many inventors came to the front with generators and lighting systems, some of which outrivalled the best efforts of European production.



Edison Lamps with Carbonized Paper Filaments

It is stated that Moses G. Farmer was the first inventor in the United States who demonstrated the fundamental principle that a series wound generator was self-exciting when its field coils and armature were connected in closed circuit with the outside load.

The Wallace Farmer machines were quite popular for a season, some of them being even exported to England in 1878.

Many other systems of arc lighting were developed and exploited about this time, each system comprising its own form of generators, lamps and appliances, and each making claims to peculiar merits, but it remained for the genius of Brush to produce an electric generator and system of arc lighting, so unique in its original conception, and so perfect and substantial in all its details, that it commanded almost immediately a leading position, which was maintained even up to within recent years.

In 1880 the American Electric Company was organized in New Britain, Conn., for the manufacture and sale of high tension constant current generators and arc lamps under the patents which had been issued to Prof. Elihu Thomson. In 1884 the name of the American Electric Company was changed to the Thomson-Houston Electric Company and the factory was transferred from New Britain to Lynn, Mass. Soon after this change the Thomson-Houston Company began to develop and manufacture generators, incandescent lamps and appliances for a low tension system of incandescent lighting.

Previous to 1879, the production of electric light for domestic use, as a competitor with gas, received little thought, but in this year Edison started to work out a commercial system of lighting with incandescent electric lamps at his laboratory at Menlo Park, N. J. Up to this time the incandescent lamp could hardly be considered as anything but a laboratory experiment, although a patent was granted to Starr for an incandescent lamp in England in 1845, and Swan, also working in this field in England, is said to have actually made and exhibited, in the autumn of 1878, a practical incandescent lamp with a carbon filament.

Edison attacked the problem with his characteristic ardor and indomitable perseverance, and with a determination to make the incandescent lamp an industrial success, or in other words, to evolve a system of electric lighting with incandescent lamps, to be so cheap, convenient and safe that it would be used for public and private lighting purposes in competition with gas.

Furnished with ample funds by capitalists who knew and appreciated his abilities, he fitted up his laboratory and workshop with the necessary appliances and employed a staff of picked men for his assistants, who worked enthusiastically almost day and night in the development of the new system.

Almost every conceivable material was tried in the effort to make a durable and satisfactory lamp filament, and agents were sent to many foreign countries to collect and forward to Menlo Park all kinds of vegetable fibres which might possibly possess the desired qualifications.

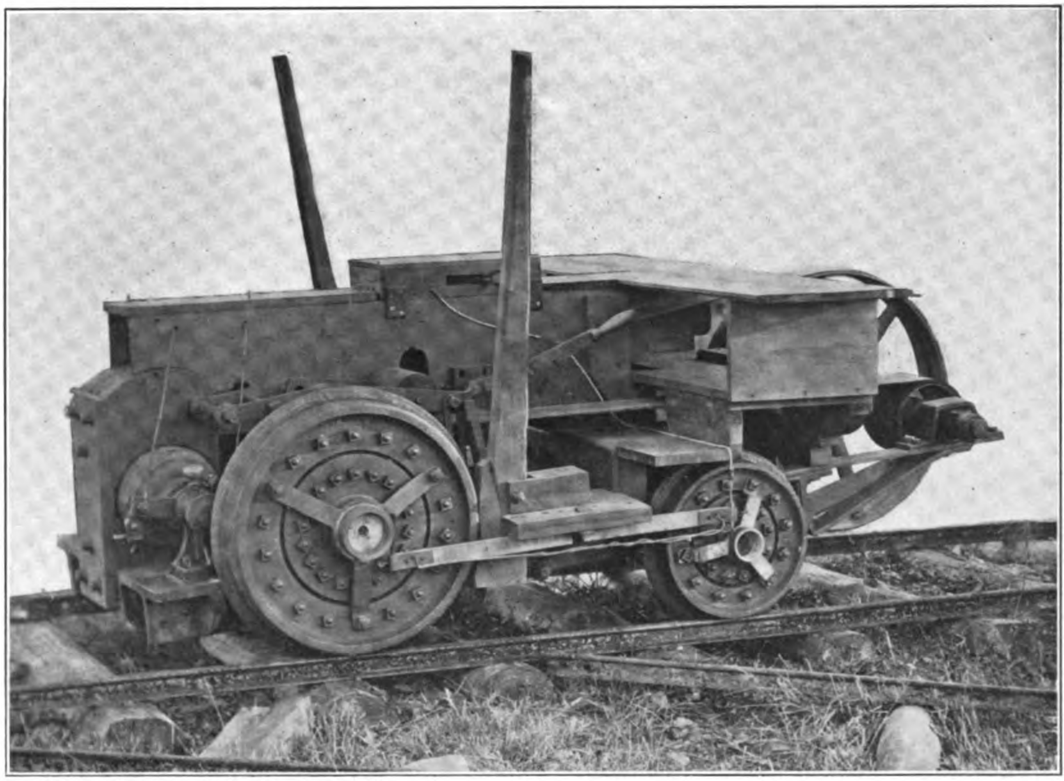
After many months of careful investigation, during which time filaments were made from a great variety of materials, such as wood, cotton, paper, graphite, lamp black, and various vegetable fibres, it was found that the carbonized outer shell of the bamboo cane gave the best results; so this material was finally adopted and used for many years thereafter.

The discovery of a suitable substance for the incandescent lamp filament was obviously only a small part of the work to be accomplished, for Edison had set himself the task of designing a comprehensive electric lighting system to be complete in its minutest details, from the generators to the lamps. It was something absolutely new and untried, inasmuch as it was a low voltage multiple arc system in which each lamp was to be an independent unit which could be lighted or extinguished without affecting any other lamp on the circuit, whereas previous electric lighting with arc lamps had been operated on the series system, involving a certain voltage for each lamp, and therefore a total voltage in direct proportion to the number of lamps included in a circuit.

Many eminent scientists both at home and abroad pronounced Edison's plans to be chimerical and practically impossible, but no discouragement could dampen his ardor or weaken his faith in final success, so the work of development steadily progressed. Shunt wound generators were designed and built; crude switches, lamp sockets and safety appliances were devised and constructed; copper wire was laboriously covered with hemp cord, painted over with coal tar and laid in the ground in wooden troughs. Wooden lamp posts were erected and fitted with large round globes of a clear glass.to protect the lamps and sockets within, and at last, in the early winter of 1880–1881, the work of installation was completed and the snow-covered woodlands for a quarter of a mile around the Menlo Park laboratory were illumined night after night by glittering rows of incandescent lamps. The surrounding residences had also been wired and were brilliantly lighted every night with the new lamps.

People came from far and near to see this wonderful exhibition which marked the beginning of the industrial era of domestic electric lighting, and the daily papers were full of the possibilities of the new illuminant.

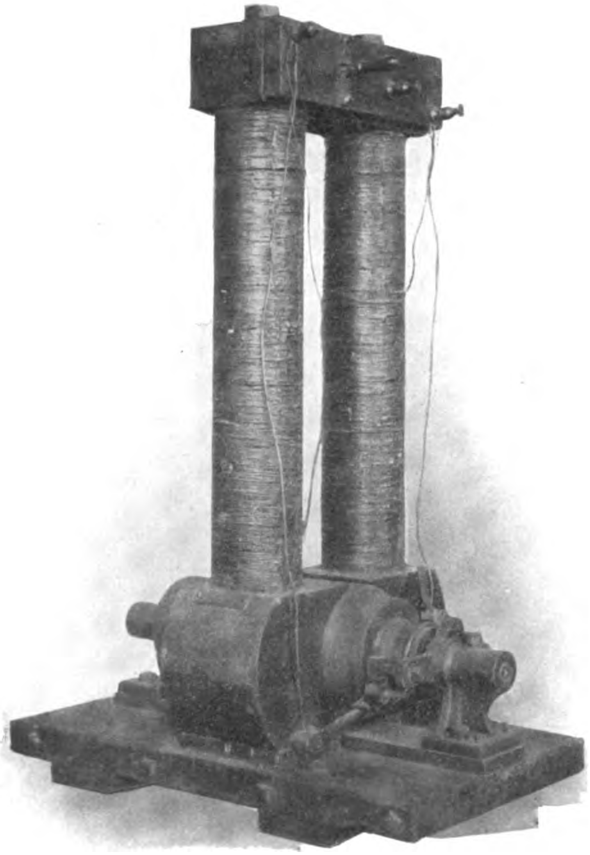
It was about this time also that Edison made his first experiments with the electric railroad. A narrow gauge track about half a mile long was laid from the Menlo Park laboratory into the country beyond. A strong truck was built and a shunt wound generator was mounted on it to do duty as a motor, a pulley on its shaft being belted to another pulley on one of the car axles. The rails were insulated from each other and from ground, and served as conductors to carry current to the motor through the car wheels, which were also insulated. Edison's first electric locomotive, which was built and operated at Menlo Park, N. J., in 1880, is now preserved as an interesting and valuable relic in the Polytechnic Institute, Brooklyn, N. Y.


Edison's First Electric Locomotive

The question is often asked, why the standard nominal rating of the incandescent lamp was fixed at 110 volts. It is believed that this rating was largely an accidental result. Edison aimed to make his standard lamp equivalent in candle-power to the light of a five-foot gas burner using a good quality of illuminating gas, which is about 16 c.p., and in his early experiments he found that with the size and length of carbon filaments which were then being made, 110 volts at the lamp seemed to produce the best average results in respect to color, candle-power and life. Thus 110 volts began to be recognized as a nominal standard for incandescent lamps, and after a time it became universal. The filament might easily have been so designed that these results would have obtained with

90, 100 or 120 volts, in which case there is no doubt that the standard nominal voltage would have been rated accordingly.

Sometime after 110 volts had become the nominal standard, it became desirable to produce a lamp of a much lower voltage, so it was decided to halve the then existing standard and make a nominal 55 volt lamp. These lamps were principally used in small isolated plants, and they never came into any general use in connection with Edison central station systems.



Early Type of Edison Bi-polar Generator

The exhibition of incandescent lamps at Menlo Park was continued for some time, until the insulation of the underground conductors, never very good, dropped so low that they could no longer be used. Thousands of visitors had in the meantime, however, availed themselves of the opportunity to see the new light, and so many inquiries and orders for electric apparatus were received, that in a short time the manufacturing facilities at Menlo Park were found to be totally inadequate. The works of the John Roach Machine Company in Goerck Street, New York City, were bought and fitted up for the manufacture of dynamos and electric apparatus on a large scale, thus rather curiously reviving the memory of old Otto Von Guercke, who about 250 years before had made the first recorded observation of an electric light, as previously related.

In 1880 Edison began to build large shunt wound bipolar generators of low voltage for direct connection to high speed engines, these units being intended for heavy central station duty.

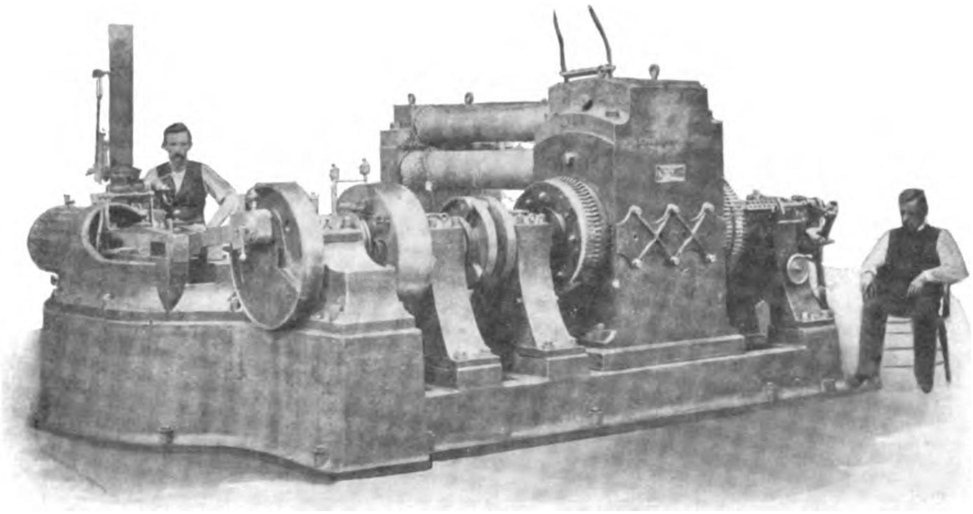
One of these "Jumbos," as they were called, created quite a sensation at the Exposition of Electricity at Paris in 1881, and several others were afterwards built and used in the Pearl Street central station in New York City; also in London, England; Milan, Italy; and other large cities.

Direct connected generators did not, however, seem to be appreciated in those days, preference being given to smaller units belted to high speed engines, this being no doubt due to the fact that the multipolar type of direct current generators had not then been developed, and the high peripheral speed necessary for bipolar machines made direct connection to engines rather undesirable.

The "Jumbo" generators, although justly considered at that time as stupendous and wonderful, were heavy and clumsy in proportion to their output. The armature of one of these generators, for example, was 5 feet long by 28 inches in diameter, and weighed about four tons. The field magnets consisted of twelve heavy iron cores ending in massive cast-iron pole pieces. These machines were driven by Porter Allen engines running at 350 r.p.m., and the complete unit weighed more than 20 tons, with a capacity of only 60 kw.

Although there was a considerable demand for small isolated lighting plants, Edison's aim from the first was to promote the installation of large central stations where electricity could be cheaply produced in quantity, and distributed from house to house by overhead or underground conductors. The first central station designed for the public service of electricity in connection with incandescent lamps was started in Holborn Viaduct, London, England, early in 1882, and on September 4th of the same year, another central station was started at 257 Pearl Street, New York City. The distributing system connected with this station was supplied by six "Jumbo" generators, and 14 miles of heavy two-wire underground conductors were laid, making the cost of copper enormous. To meet this difficulty, Edison invented the well-known three-wire system which is now in universal use.

The first central station built for the three-wire system was installed in the town of Sunbury, Pa., and was started for public service on the 4th of July, 1883.



Direct Connected, Edison Bi-polar "Jumbo" Generator

As this was the banner three-wire central station, it may be interesting to review briefly some details concerning it.

Early in the spring of 1883, Edison had some tests made at the Goerck Street Works on his newly invented three-wire system, the results of which were so satisfactory that he at once determined to put the system into commercial operation. As before stated, the town of Sunbury, Pa., had been selected, and a small wooden structure was built on the outskirts of the town to serve as the central station. The building contained an engine and dynamo room, boiler room and meter room. The boiler was a Babcock & Wilcox, and the engine a high speed Armington & Sims, which was belted to two Edison bipolar generators having a total capacity of about 400 16 c.p. lamps. The bus bars were made of No. 000 copper wire, straightened out and fastened with iron staples to the wooden sheeting of the dynamo room without any pretension at insulation. The instruments consisted of two ponderous pressure indicators, and one rudely built ammeter interpolated in the neutral bus to show when the load was out of balance.

In view of all the refinements in electric apparatus which are now considered necessary for the successful operation of a modern generating plant, it is interesting to look back at the few rough and crude appliances with which the first central stations were furnished, but with which they were nevertheless successfully operated.

This Central Station System was started by Mr. Edison personally on July 4, 1883. Similar installations in various other cities followed rapidly, twelve other systems being started within a year from the above date.

Incandescent lighting was now fast becoming a public necessity, and as all central station plants that had so far been installed appeared to be financially profitable, the business grew very rapidly and promoters became rich in the organization of new electric lighting companies.

The limitations of the low tension three-wire system soon became apparent, however, especially in suburban districts where the lighting was scattered and located at some distance from the source of supply, as the cost of conductors made it unprofitable to transmit low tension current for more than about a mile from the generating station. Edison was opposed to the use of high tension current for lighting purposes, for which reason he never devoted much time or thought to the development of A.C. apparatus. However, the Westinghouse, Thomson-Houston and other electric manufacturing companies began to build up a good business in these lines, and later on, when Tesla entered the field, the patents covering his valuable inventions were purchased by the Westinghouse Electric Mfg. Company. The acquisition of these patents gave to that company a commanding influence in the industrial application of A.C. apparatus, and the adaptability and flexibility of the alternating current system soon became apparent in connection with the transmission and distribution of current for incandescent lighting.

Development along these lines was pushed with great energy and skill by the Westinghouse and Thomson-Houston Companies, but for several years progress was hindered by the difficulties encountered in coupling alternating current generators in multiple, and also for the reason that no alternating current motors had been developed which would bear comparision with existing types of continuous current motors. These and many other drawbacks which surrounded the introduction of the A.C. system were gradually diminished or entirely eliminated as new developments were unfolded, and to-day we see the two systems harnessed side by side, or mutually interchangeable, and by intelligent handling, producing results which only a few years ago would have been considered impossible.

It is stated on good statistical authority that the enormous sum of more than one thousand million dollars is now invested in this country in central station electric lighting plants, not including power and traction companies. Considering the fact that the first central station was installed only about 25 years ago, we may well be inclined to wonder what will be the future history of this marvelous industry which has been growing steadily from its birth at an average rate of over $40,000,000 per annum, and has in the comparatively short period of quarter of a century attained such magnificent proportions.

THE ADVANTAGES OF THE VARIABLE SPEED MOTOR FOR DRIVING TESTING MACHINES

By J. A. Capp

Chief of Testing Laboratory,
General Electric Co.

Not very many years ago a testing machine was looked upon as a sort of luxury, desirable but not essential. More recently, however, the engineer has found it increasingly necessary to have exact knowledge of the properties of the materials entering into the structures and machinery for which he is responsible. Now, the problem is to get the most out of the testing machine. Formerly, the time consumed in making a tensile test of a specimen representing a forging or rolled

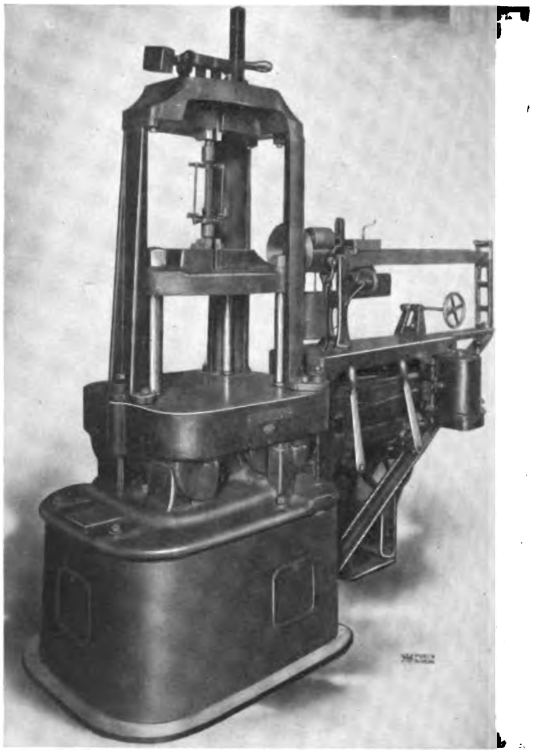


Fig. 1. Olsen 3-Screw Testing Machine, Fitted with General Electric CR-3, 3 h.p. Motor and R-75A 5 h.p. Controller, Giving Speeds of from 2/10 in. to 4 1/4 in. per Minute, with Main Driving Clutch. Capacity 150,000 Lb.

shape was not a factor to be considered, because tests were made at relatively infrequent intervals, but now that specimens representing the entire output of the forge or rolling mill must be pulled, the testing machine sometimes had a limiting influence upon shipments, until it was speeded up to rates formerly considered inadvisable if not impractical. The driving of the testing machine and its speed control has become an important question to the testing engineer.

The results required from a tension test are:

Ultimate strength or breaking load;
Elastic limit or yield point;
Elongation;
Contraction of area.

The ultimate strength is obviously the maximum load reached in the course of the test, while the elongation and the contraction are measured after the specimen has been removed from the testing machine. There is seldom any difficulty in obtaining these properties, nor need there be any doubt about the values reported by a reasonably careful observer. The nominal elastic limit reported may generally be better defined as the "yield point," and is located at that load at which the rate of stretch of the specimen, with uniformly increasing load, suddenly greatly increases. When the testing machine is driven at a relatively slow, steady speed, this point is marked by the sudden dropping of the beam, which the operator has kept floating in balance by moving out the poise at a fairly even rate. The increase in rate of stretch is so great that the specimen does not support its load, and the beam remains down for several seconds, or even a full half minute, before the specimen picks it up, after which its stretch-rate uniformly but rapidly increases until the maximum or breaking load is reached. Hence, after the yield point is passed, the operator must move out the poise at a slower and slower rate, with uniform driving of the testing machine. It is customary to speed up the testing machine very materially as soon as the yield point is located, so as to save time.

The yield point is also indicated by dividers, the points of which are held in prick punch marks; when the yield point is reached the point of the dividers slips out of its punch mark. Sometimes the dividers afford the only means of determining the yield point, for the rate of pulling is often such that there is no well marked dropping of the beam.

When testing machines are belt driven, and frequently, indeed, when driven by electric motors, the speeds obtainable are limited to those given by the manipulation of the several clutches, with the result that speed changes are abrupt jumps. The changing of the clutches sometimes requires that the machine be stopped, or at least that power be shut off for an instant while the clutch is being thrown over and the speed adjustment made. This lack of flexibility has resulted in the selection of such driving speeds as will give to the testing machine the two speeds required for testing—a slower speed up to the yield point, and a faster speed beyond it—with one change of the clutches. The slower speed is oftentimes so great that the operator has difficulty in moving the poise fast enough and with sufficient uniformity to keep the beam floating in approximate balance. In such cases the best that can be expected is a guess at the location of the yield point.

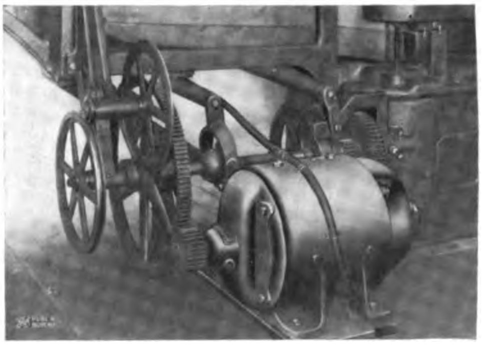


Fig. 2. Rear of Olsen 3-Screw Testing Machine, Showing Driving Motor and Gearing

Following the speeding up of testing machines, there has been considerable discussion among engineers as to the influence of rate of pulling upon the results obtained; or perhaps it would be better to say, upon the apparent values of the properties of the materials determined by the tests. It has seemed to the author that this discussion may be summed up by saying that speed of testing influences only the accuracy with which the tests may be conducted, because no practical speed change seems to have any other direct results. It is obvious that when the testing machine is driven so rapidly that the operator cannot keep it in balance, accurate results cannot be expected. The yield point, which is taken "on the wing," will always be placed too high, for in his efforts to have the poise keep up with the load, the operator will nearly always overshoot the mark, the man at the dividers noticing the slip of the point and calling out "read."

The variable speed motor and controller presents a very satisfactory solution of the whole problem of speed of testing. A 3 to 1 range of speed, obtainable by easy gradations (not jumps) by the turning of the handle of the controller, permits the operator to drive his machine at that speed at which he can most certainly and accurately keep the beam floating in balance. Once past the yield point, the throwing over of the speed clutch and simultaneous slowing down of the motor enables him to pick up the load at about the same speed as before, and to gradually increase it as the stretch-rate increases, thus keeping the travel of the poise up to about the maximum rate consistent with accuracy. Operating under these conditions, testing may be done without risk of errors due to guessing, and the time of testing reduced to the lowest practical limit.

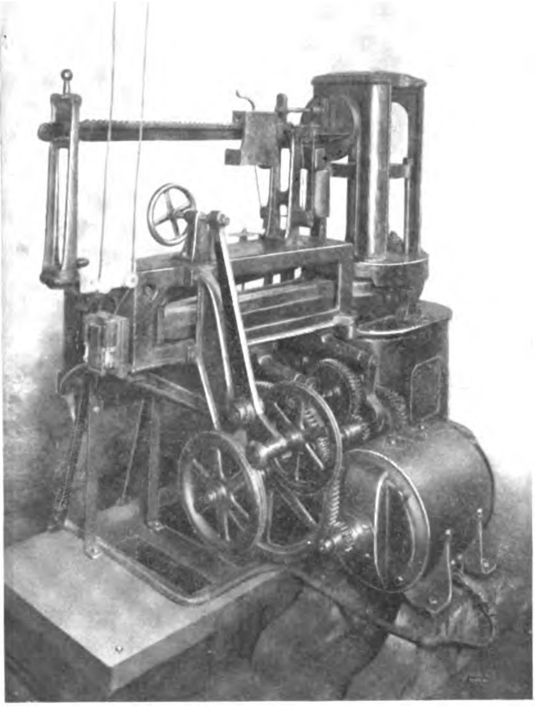


Fig. 3. Olsen 4-Screw Testing Machine, Fitted with General Electric CR-2, 2 h.p. Motor and R-75-A 2 h.p. Controller, Giving Speeds of from 2/10 in. to 5 7/10 in. per Minute, with Main Driving Clutch. Capacity 30,000 Lbs.

The machines in the testing laboratory of the General Electric Co., at Schenectady, N. Y., have all been equipped with variable speed motors and controllers, as shown in the illustrations. Fig 1 is a front view of an Olsen 3-screw testing machine of 150,000 lb. capacity, fitted with a CR-3, 3 h.p., Form B, 230 volt shunt wound motor, and an R-75-A, 5 h.p., 250 volt controller. Fig. 2 shows the motor and gearing, located at the rear of the testing machine. Using the main driving clutch, speeds ranging from $\frac{2}{10}$ in. to $4\frac{1}{4}$ in. per minute are obtainable, and it is possible to operate the machine under load anywhere in this range. For ordinary testing, the speed range from $\frac{2}{10}$ in. to $\frac{7}{10}$ in. per minute, obtainable by the normal speed adjustment of the motor through the controller, is ample. The higher speeds are only occasionally required in testing, but, of course, are very useful in adjusting the draw-head to the desired height. All these speeds are available in both directions, the motor being reversed by reversing the direction of rotation of the controller handle. When it is required that compression tests be made, very much slower speeds are necessary, and these are obtained by driving the machine through the V friction gearing instead of the main driving clutch. With the V friction, the available speeds of the draw-head are from about $\frac{1}{100}$ in. to $\frac{3}{100}$ in. per minute.

Fig. 3 shows an Olsen 4-screw testing machine of 30,000 lb. capacity, fitted with a CR-2, 2 h.p., Form B, 230 volt shunt wound motor. This machine was originally driven by a constant speed motor which was afterward replaced by the variable speed motor shown. The cut shows the ease with which the new motor was fitted into place. This motor is operated through an R-75-A 2 h.p. 250 volt controller, placed upon the front of the machine frame in a similar position to that of the controller for the previously described machine shown in Fig. 2. Using the main clutch, it is possible to obtain with this machine draw-head speeds of from $\frac{2}{10}$ in. to $5\frac{7}{10}$ in. per minute, and with V friction gearing, about $\frac{1}{24}$ in. to $\frac{1}{8}$ in. per minute.

In constructing the 150,000 lb. testing machine (Figs. 1 and 2), provision was made for mounting the driving motor, while in the case of the 30,000 lb. testing machine (Fig. 3), the present motor replaced the motor for which provision was originally made.

Fig. 4 shows how a testing machine, originally belt driven, may be operated by electric motor. In this case the pulleys for open and crossed belts, together with their friction clutches, were removed, and a single spur gear was mounted upon the main shaft. This shaft is driven by a CR-5, 5 h.p., Form B, 230 volt shunt wound motor, operated through an R-65-A controller equipped with special resistances to permit continuous operation on the starting points. With this installation, speeds ranging from ¼ in. to 3¼ in. per minute are obtainable for testing purposes; and for adjustment, speeds up to about 5 in. per minute are available.

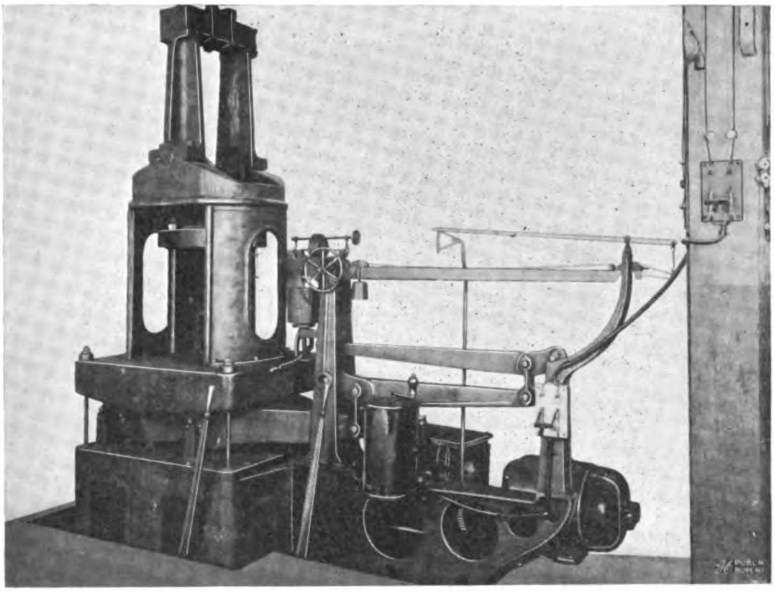


Fig. 4. Belt-Driven Testing Machine Adapted to Motor Drive Fitted with CR-5, 5 h.p. Motor and R-65-A Controller

Mention has been made of the advantages of ready adjustment of draw-head speed through the simple turning of the controller handle, when making the ordinary tension tests of specimens representing forgings, rolled shapes and the like. The utility of this easy control of speed is even more marked when carrying out some of the special tests which must often be made in the testing machine; for example, the testing of a peculiar shape used in construction, to determine not only its strength but the behavior of the shape when under stress, and the characteristic way in which failure occurs, as well as the point of failure. Such a test requires the frequent stopping of the machine to permit of observation of the part under stress, as well as the making of measurements of deformation. The machine must often be reversed to permit repetition of observations at lower loads, and to ascertain if recovery after release of the load is partial or complete.

In fact, so great is the gain derived from the application of the variable speed motor to the driving of the testing machine, that it has made possible many tests, upon both prepared specimens and full sized parts of machinery, that could not otherwise have been easily made. It has, therefore, permitted the designer to check, under practical conditions, the calculations he has made in arriving at the safe dimensions of parts under stress.

GREENFIELD ELECTRIC LIGHT & POWER CO., GREENFIELD, MASS.

By Ira M. Cushing

Greenfield, Mass., a prosperous little city of about 10,000 inhabitants in the western part of the state, now has one of the most thriving and up-to-date electric light and power plants of any city of its size in New England.

The Greenfield Electric Light and Power Company has recently made a large addition to its former station, and has installed the latest type of apparatus, which will facilitate the dispensing of power and light to customers. The station now contains two 400 kw., 2300 volt, 60 cycle, 3-phase generators, which were part of the old equipment, and one new 500 kw. (rated for 85 per cent. power factor), 2300 volt, 60 cycle, 3-phase generator direct connected to a McIntosh-Seymour horizontal cross-compound 750 h.p. engine. One of the 400 kw. generators is belted to a jack-shaft, which in turn is belted to two engines aggregating 750 h.p. The other 400 kw. generator is belted direct to a 600 h.p. cross-compound Corliss engine. All of the engines are horizontal cross-compound, condensing, using water from a pond in front of the station for condensing purposes. This pond holds about 1,500,000 gal. of water. At the time the accompanying photograph of the station was taken, the water had been drawn out to allow for repairs.

The steam generating part of the plant consists of four boilers, aggregating 1400 h.p., and delivering steam at 135 lb. pressure. The steam end of this plant, is, however, only an emergency system, as ordinarily the power is received from two water power sources.

At Shelbourne Falls, a distance of 8 miles from Greenfield, the Company has installed two 400 kw., 10,000 volt, water-wheel driven generators. The Company has also just completed a power line from the power plant located at Turner's Falls, a distance of 4½ miles. The plant at Turner's Falls has an aggregate capacity at present of about 2000 kw., the line, however, being designed for a maximum of 1000 kw. This makes the total available power, aside from the steam driven units, approximately 1800 kw., or nearly 2500 h.p. The Company is therefore in good shape to handle a large increase in business.

The 10,000 volt current received from Turner's Falls and Shelburne Falls is stepped down to 2300 volts by two banks of transformers, one bank consisting of three single-phase oil-cooled transformers of 250 kw., 60 cycle, 10,000/2300 volts each, the other bank of three air blast single-phase transformers of 300 kw., 60 cycle, 11,000/2300 volts each.

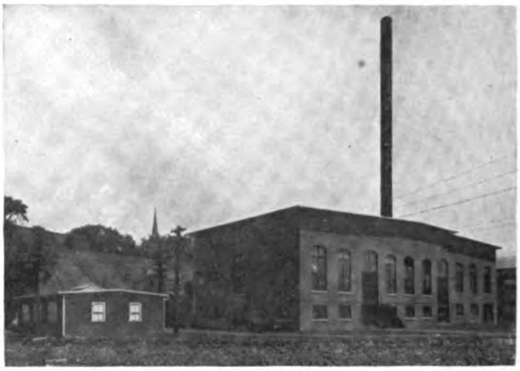


Fig. 1. Power House

This second bank of transformers is kept cool by two blower-sets, each consisting of a fan direct connected to a 2 h.p., 220 volt, three-phase motor. Each blower set is capable of supplying sufficient air for the three transformers.

The 10,000 volt current is also fed direct from the 10,000 volt buses to the rotary transformers, and to an outgoing line to Hadley.

Voltage regulating devices, which maintain the voltage on the lighting circuits practically constant, are installed at the two power houses, and also in the Greenfield station.

The Greenfield station is connected by telephone with the private system of the Railway Company, and with the power houses by a line of its own. The power houses are also connected with the New England Telephone Co.'s lines.

The Company has a large and commodious office on Federal Street, where it carries and displays an extensive line of electrical appliances.

Fig. 1 shows an exterior view of the station, with the battery house for the railway at the left. Attention is called to the large windows, which give the station an abundance of light and ventilation. This illustration also shows the 10,000 volt lines coming in at the near end of the left-hand side of the station.

At the far end are shown a framework and the poles for supporting the outgoing 2300 volt lines for light and power throughout the city.

Fig 2 shows the direct connected 500 kw. three-phase unit; also, a 20 kw. motor-driven exciter in the foreground, and a 25 kw. turbo-driven exciter in the background. The motor-driven exciter is connected to a 2080 volt, form L, three-phase induction motor, the starting handle of which can be readily seen. Provision has been made for the installation, at some future date, of a 1000 kw. steam-driven direct connected unit, space for which is shown in the left-hand side of Fig. 2.

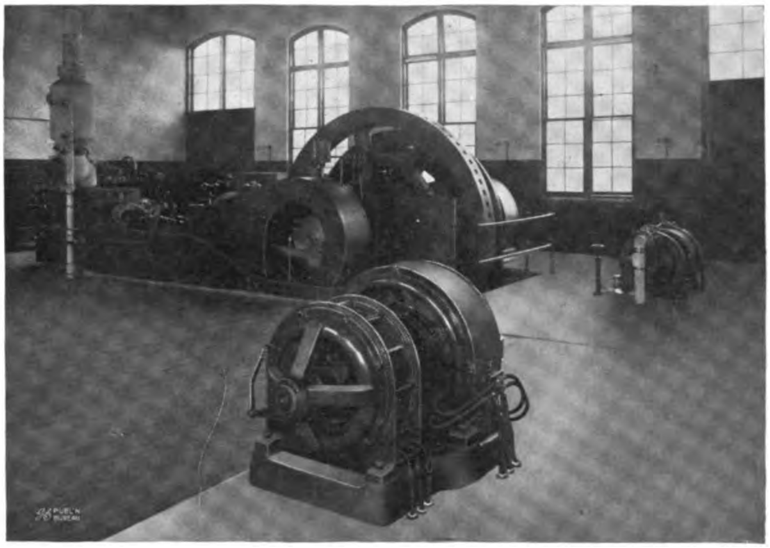


Fig. 2. 500 Kw. Three-Phase Alternator; 20 Kw. Induction Motor-Driven Exciter in Foreground; 25 Kw. Turbo-Driven Exciter in Background

Fig. 3 is a front view of the switchboard, and a general view of the 10,000 volt and 2300 volt lines as they come into the station. The turbo exciter is also shown in the foreground.

Fig. 4 gives an excellent view of the framework back of the switchboard, taken from the right-hand end. This shows very nicely the method of supporting the 2300 volt outgoing feeder lines, as well as the incoming 10,000 volt lines, and their respective potential and current transformers. The lightning arresters for the 10,000 volt lines are also plainly visible, with disconnecting switches above and choke coils mounted on the pipe framework beneath the platform. The lightning arresters for the 2300 volt lines are mounted on the wall immediately below the point at which the lines leave the building, and can just be seen at the right of this cut. The lightning arrester equipment is of the very latest type, and it would seem that the Company should be thoroughly protected from lightning disturbances on its lines.

Fig. 5 shows a back view of the 2300 volt side of the switchboard, the 2300 volt oil switches mounted immediately back of the panels, and, in the background at the right, the cells containing the oil switches for the 10,000 volt lines. At the back of these cells can be seen the pot heads through which pass the 10,000 volt lines that are to be carried beneath the floor in conduit.

Fig. 6 shows a view in the basement, just beneath the switchboard. Overhead, in the immediate foreground, can be seen the oil switch mechanisms whereby the switches in the cells are controlled from the front of the switchboard. In the middle background, and to the left, the 10,000 volt transformers which reduce the voltage to 2300 for city distribution are visible. At the right can be seen the feeder regulators which regulate the voltage of two of the principal feeders. Immediately behind these regulators, and a little to the left, are located the transformers and other apparatus for controlling the mercury rectifiers. In this station there are two 50 light series mercury arc rectifiers. The oil tanks for these rectifiers are immediately behind the feeder regulators, and cannot, therefore, be seen.

Fig. 7 shows the railway apparatus located in this station, and incidentally, where the old station joins the new. In the immediate foreground are the two rotary converters, the 300 kw. at the right, the 200 kw. at the left. The switchboard in the background controls these two rotaries, the battery, and two outgoing feeders.

The system of connections in this station is quite flexible, and lends very readily to continuity of service, which is of prime importance in city lighting and power work.

Referring to Fig. 3, the first eight panels of the switchboard, counting from the left, control the 10,000 volt circuits. The first two panels are for controlling the transformers for the two rotaries for the railroad. The third panel controls the line running to Hadley, 19½ miles long, at the end of which is a 480 kw., 2300 volt synchronous motor driving two 600 volt, 200 kw., direct current generators for the Connecticut Valley Street Railway Co. The fourth panel is a bus tie panel, enabling the operator to connect together the two incoming 10,000 volt lines when the occasion demands. The next two panels (5th and 6th) control the lines from Turner's Falls and Shelburne Falls. The next two panels (7th and 8th) control the two banks of transformers which step the high voltage down to 2300; these panels control both sides of the transformers. One bank of transformers consists of three oil-cooled transformers rated at 250 kw.

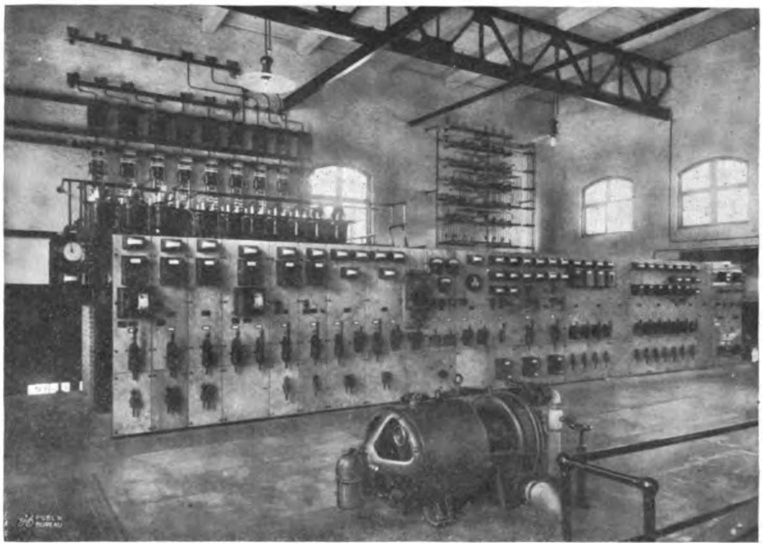


Fig. 3. Switchboard and High and Low Tension Lines

each, and the other of three air blast transformers rated at 300 kw. each.

The ninth panel is the Type TA regulator and induction motor panel. This regulator controls the voltage of the exciters and generators in this station when the steam plant is running. However, when the plant is not running, and power is being taken from the power houses at the falls, regulators at each of these stations keep the voltage constant at Greenfield.

The tenth panel controls the direct current side of the exciter sets. The eleventh panel contains a ground detector for the 2300 volt lines, and two oil switches, which are so connected that the 500 kw. generator can be connected to either bank of transformers, independently of the 2300 volt buses. This arrangement was desired so that the railway might be supplied with 10,000 volt current from this station, independently of the lighting system. This is another precaution in the matter of keeping constant voltage on the lighting circuits. If the fluctuation on the railway system should become so bad as to affect the lighting, it can be isolated completely.

The eleventh, twelfth and thirteenth panels control the three generators located in this station. The next six panels control the three-phase and single-phase 2300 volt power and lighting circuits for the city. Each circuit is equipped with an indicating and a recording wattmeter so that accurate record can be kept of all power that is delivered to the city. The last three panels at the right of the switchboard control the mercury rectifier outfits and two 50 light arc circuits.

As stated above, the street railway company operating in this district obtains power from this station. This company is known as the Connecticut Valley Street Railway Co., and has about fifty miles of track connecting Greenfield with Northampton, Amherst, Turner's Falls and Miller's Falls. It operates a small water power plant at the Miller's Falls extremity, furnishing D.C. current; but most of its power is furnished by the lighting company at Greenfield in the form of A. C. current at 10,000 volts. This power is carried from Greenfield, down the Connecticut Valley on the railway company's transmission line erected over a private right of way, to a sub-station at Hadley, situated about half way between Northampton and Amherst. The other sub-station, being located at Greenfield, is incorporated in the lighting company's plant.

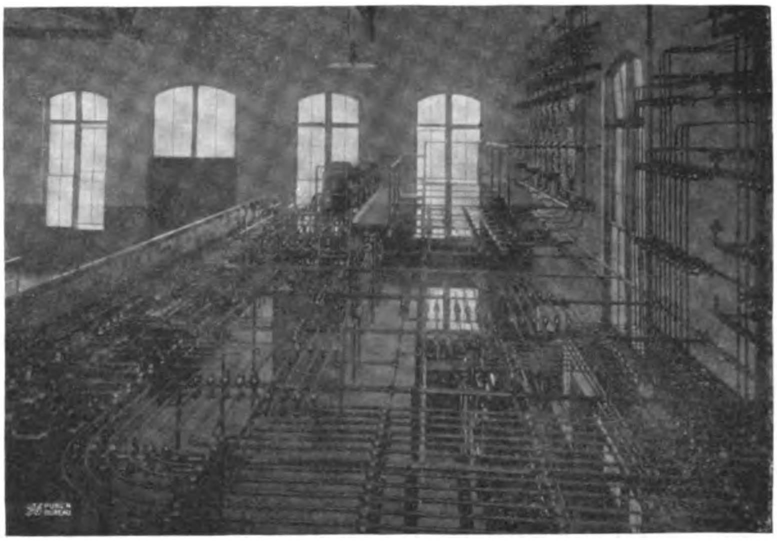


Fig. 4. Framework Back of Switchboard Showing Method of Supporting 2300 Volt Outgoing Feeder Lines

An unusual feature in connection with the Greenfield sub-station is the use of a storage battery to control the effects of the fluctuations of the railway load on the A.C. side, in order to make it easier and more economical for the lighting company to handle this load. The battery is housed in a small wooden structure just outside the main station, and consists of 288 cells made by the Electric Storage Battery Co. This battery is connected in on the D.C. bus of the railway system, subject to the automatic control of the regulating apparatus, which in turn is operated by a current transformer placed in the A.C. railway load circuit so that the entire railway load passes through it. Should a momentary heavy demand for power fall on the distant sub-station at Hadley, it will be supplied from the storage battery, which will have its effective voltage automatically increased by its regulating apparatus until the rotary at Greenfield inverts and furnishes the bulk of the extra A.C. demand, instead of allowing it all to fall back on the water power plant. At such a moment, the local D.C. load on the Greenfield sub-station is assumed by the battery. This inversion of the rotary is, however, not very frequent, because ordinarily the assumption of a portion of the D.C. load at Greenfield by the storage battery is sufficient to compensate for the increase of load at Hadley. If the opposite effect occurs; that is, if the load falls off, the battery will continue the normal demand on the power station by taking a charge equal to the falling off in load. The net result of this arrangement is, that it is possible to carry on the water-wheels a rapidly fluctuating railway load, which, if not so regulated, would be constantly exceeding the available capacity, although the average load would be well within this value. During the day the entire load of the station, both railway and town load, is operated from the same machine, with a resulting voltage regulation of within 5 per cent.

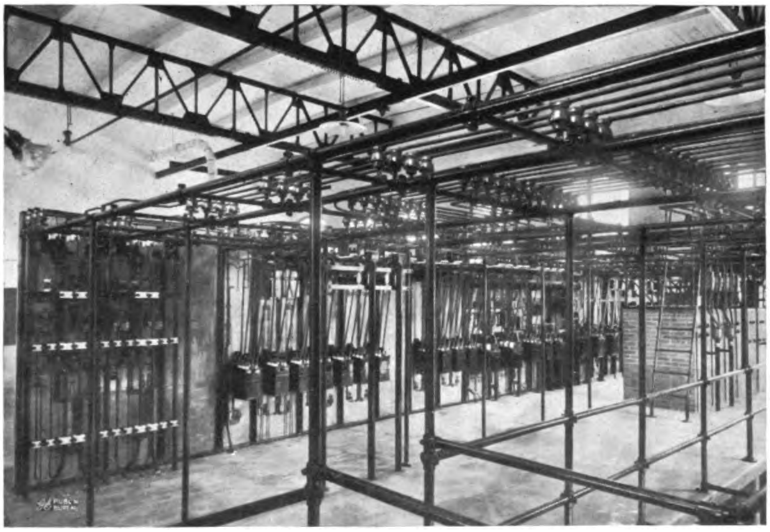


Fig. 5. Rear of Switchboard Showing High and Low Tension Switches

Part of the regulating apparatus for the battery may be seen on the switchboard in Fig. 7. It is mounted on the last panel at the right, just behind the 300 kw. rotary. This regulator is known as the carbon regulator, and is controlled by the energy in the railway circuit. It controls the fields of a small motor generator set, this set in turn exciting the fields of the booster. This booster consists of a D.C. machine driven by an induction motor, and so connected that it receives through its armature all current which passes in or out of the storage battery, regulating the voltage change at the terminals of the battery as required.

The battery house, which is shown on the left in Fig. 1, is of wood, with concrete floor. The 288 cells (Type F15) are mounted in rows on wooden frames, which in turn are supported on insulators.

The average load on the station for a 12 hour day, including the railway, ranges from 700 to 800 kw. For a 24 hour day the average is between 425 and 550 kws. The present average day load, during the so-called "hard times," is over 300 kw. The night lighting load peak is over 250 kw., and consists of the commercial lighting and arc circuits.

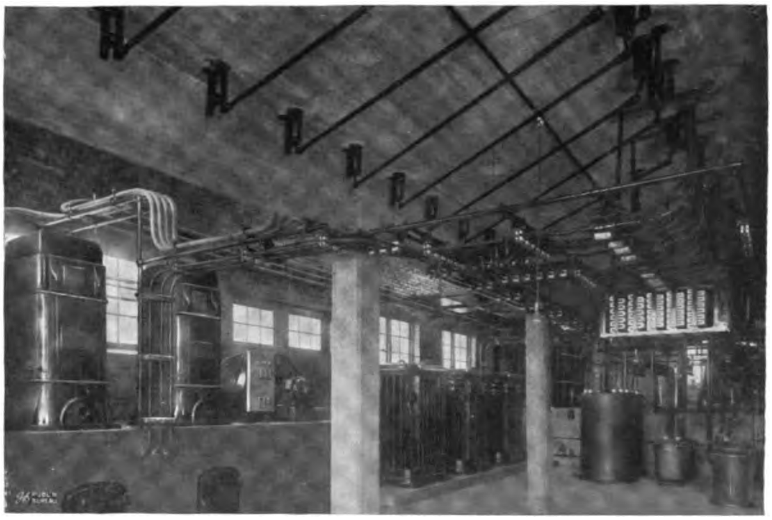


Fig. 6. View in Basement, just Beneath Switchboard

The Company has over 1000 h.p. in motors connected to its lines, with a total of over 170 motors. This does not include fan motors, dental lathes, etc. Included in this motor installation are one 60 h.p., 2080 volt motor, and one 50 h.p. motor which was installed some little time ago, but which is unfortunately wound for 220 volts. The Company's policy is to advocate the installation of high voltage motors; this, it is believed, is a step in the right direction. The Company has 57 power customers and some 700 light customers connected to its lines, with a total of 842 meters. An equivalent of 14,760 16 c.p. lamps are connected to the system. The Company is recommending very strongly the use of tungsten lamps for store and heavy lighting, and is installing large numbers of them on exceptionally liberal terms.

Notwithstanding all the intricate connections, the total loss on all lines is only between 10 and 15 per cent. This seems rather remarkable, and shows that the Company has been very careful in all of its installations, sufficiently insulating all construction so that the leakage is very small. The Company has gone to considerable expense in installing lightning arresters on the 2300 volt feeder lines throughout the city. The results from these during the various electrical storms have been very satisfactory. For the further protection of the premises and person of the customer, the Company intends eventually to operate the commercial power and lighting systems on separate circuits, and to ground one wire of the 110 volt secondary of the latter.

With new power customers, the policy of the Company has been to recommend a motor of sufficient capacity to take care of his present load only. This means that the motor runs fully loaded, thereby giving its maximum efficiency. Incidentally, it assists the Lighting Company to maintain a better power factor on its system. If the customer desires an increase of capacity in the future, another motor is recommended, and, when feasible, the small motor will be exchanged for a larger one. The Lighting Company recommends that the customer use individual drive as much as possible.

Besides supplying light and power, the Company has over 200 flat irons on its lines, as well as glue pots, water heaters and cooking apparatus, including one 40 gal. water heating tank, and a 20 kw. drying oven for drying japan on metal work. One of the power customers has about 72 motors, ranging from ½ to 25 h.p. in size. The Company also makes free renewal of all burned out incandescent lamps that are not broken.

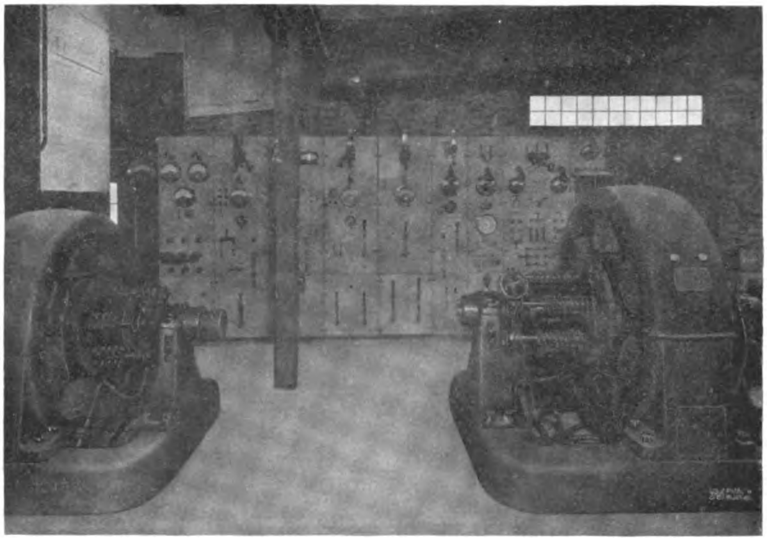


Fig. 7. Rotary Converters and Switchboard

The charges made for electric lighting vary from 15 to 8 cents per kilowatt hour, depending upon the amount of power used per month. For amounts under 75 kw. hrs. per month, the charge is 15 cents; over 600 kw. hrs., 8 cents. A minimum charge of $1.50 is made; also, a discount of 10 per cent. for cash within 10 days.

For power, the rates range from 6 cents per kilowatt hour, with a monthly total of less than 100 kw., down to 1.8 cents for over 10,000 kw. hrs. per month.

That the Company is in a prosperous condition, and apparently has a large number of satisfied customers, is evidenced by the increase in business during the last two years, which was as follows:

Lighting business, 50 per cent.;
Street lighting, 30 per cent.;
Railway load, 100 per cent.;
Power business, 200 per cent.

With this new installation, the Company is amply prepared for an increase of 100 per cent. along the power and lighting circuits, without any change in the station apparatus. With but a slight change, including a few additions to the switchboard apparatus, the Company will be prepared for a still further business increase.

The arc circuits, of which there are two, consist of seventy-one 4 ampere luminous arc lamps and sixty-six 4 ampere 40 c.p. series incandescents. One circuit includes 33 arc lamps and 32 incandescents; the other, 38 arc lamps and 34 incandescents.

The Company has had excellent results in placing these incandescent lamps in series with the arc lamps, the incandescent lamps apparently improving the power factor of the system.

CONTROLLING BOARD FOR THE POWER PLANT OF THE SALT RIVER PROJECT

By S. E. M. Henderson

The Salt River Project of the United States Reclamation Service is more or less familiar to a great many individuals on account of the wide advertising it has received, due to the immense size of the dam and storage basin, the latter being the largest artificial reservoir in the world; and also because the large town of Roosevelt will be wiped out of existence when the reservoir is filled. About 200,000 acres of arid land near Phœnix, Ariz., is to be irrigated by a canal system fed from the main reservoir, and it is intended to irrigate an additional 40,000 acres by underground waters, made available by the installation of pumping stations at suitable points. Two of the incidentals are a 6,000 kilowatt hydro-electric power station and a 45,000 volt transmission system.

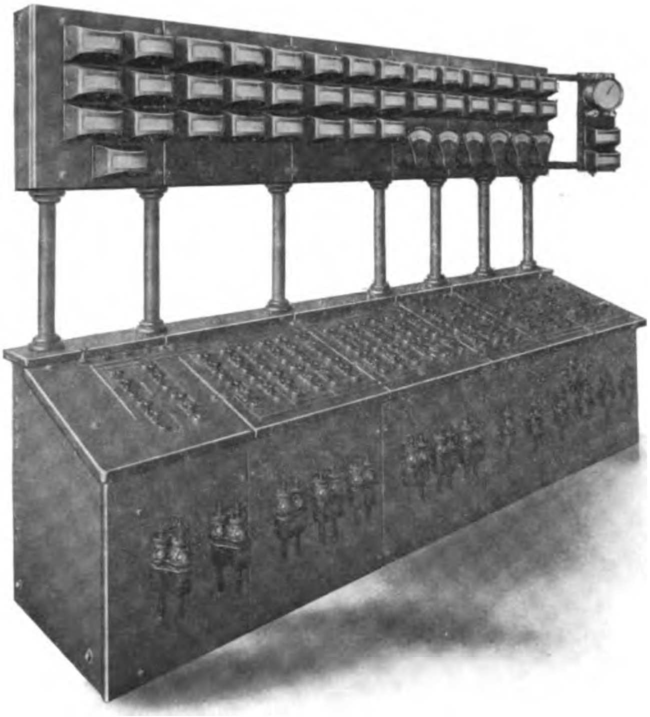


Fig. 1. A.C. & D.C. Control Switchboard

The primary object of the generating station referred to above, is to provide power for the operation of these pumping plants, and it is expected that several other generating stations will be constructed at various points to provide still more power. A market for surplus power can easily be found in the towns in the Salt River Valley. A "temporary" plant has been in operation for some years at the Roosevelt dam to supply power for the operation of the cement mill, construction machinery, lighting of the town, etc., and some of the machines in this station are to be transferred to the new power plant.

The purpose of this article is to describe the controlling board which has recently been completed for installation in the new power station.

The alternating current switchboard selected by the Government engineers for controlling the apparatus in the main station is an excellent illustration of recent "bench" control board construction. It is of the "open" type, that is, there is a space left between the instrument sections and the control bench, so that the switchboard operator can have an unobstructed view of any part of the generator room without going to the end of the board, which is located at the edge of the gallery, about 18 ft. above the main floor. This benchboard is equipped for the control of the following circuits, the exciter switchboard being independent and of the ordinary vertical construction.

6–2300 volt 1060 kv-a. 25 cycle 6-phase 3-wire generators;

6–2300 volt delta/45,000 volt Y, 1060 kv-a. 25 cycle 3-phase banks of transformers, grounded neutral;

2–45,000 volt 6000 kw. 3-phase outgoing lines.

Fig. 2 shows the system of connections specified by the Government, one line in this diagram representing the three phases.

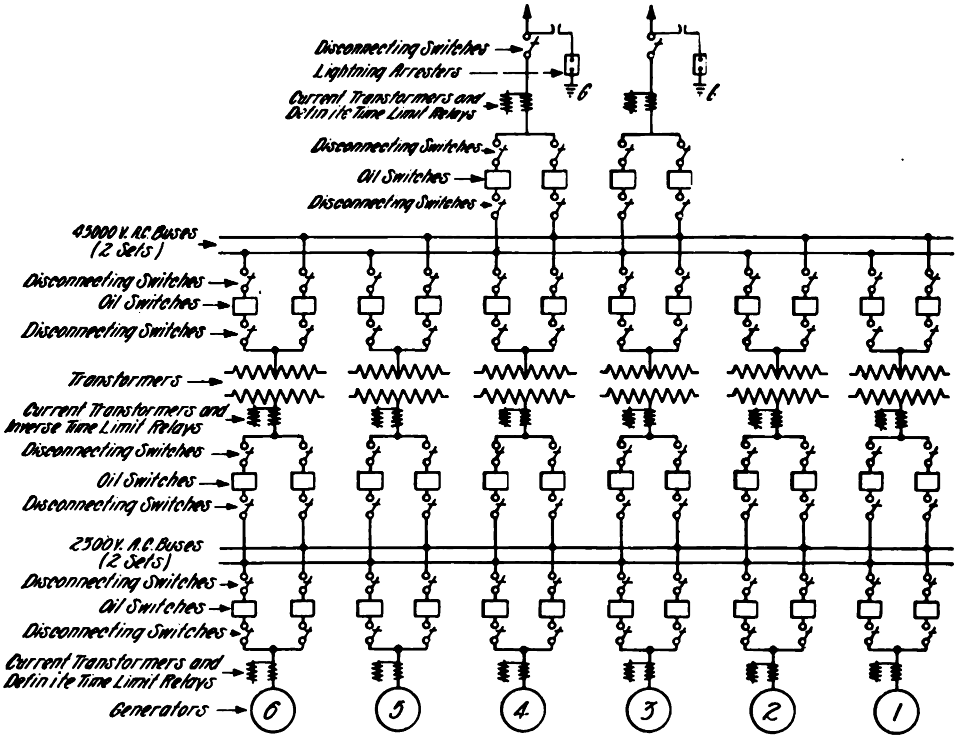


Fig. 2. Diagram of Connections

It will be seen that both high and low tension buses are in duplicate, allowing ample flexibility for operation, testing, inspection and repairs. Two electrically operated oil switches are used in every circuit, and complete control of the system is therefore obtained at the benchboard. This arrangement is advantageous where it is important that there should be no shut downs for an appreciable length of time. With more than two transmission lines it would probably have been advisable to modify the connections to allow of isolating any line for testing purposes after the automatic switch had been tripped by a short circuit or other line trouble.

All protective relays used on this board are of the time limit type, in order to prevent shut downs due to momentary overloads. The definite time limit overload relays on the lines will, of course, be set for such a current and time that they will take care of overloads or short circuits external to the station. Generator relays are also definite time limit overload ones, and will be set so that the generator switches will be tripped only on account of large exchange currents at the time of synchronizing. Inverse time limit overload relays are used on the transformer circuits and are so connected that trouble in any transformer will automatically disconnect all the transformers, but will leave the generators operating in parallel on the low tension bus. That the Government engineers anticipate but little trouble with the transformers is evidenced by the fact that no provision is made in the transformer protective devices for selective operation. By using series inverse time limit overload relays on the high tension side of the transformers, in addition to the low tension relays, only the defective bank of transformers would be disconnected in case of trouble.

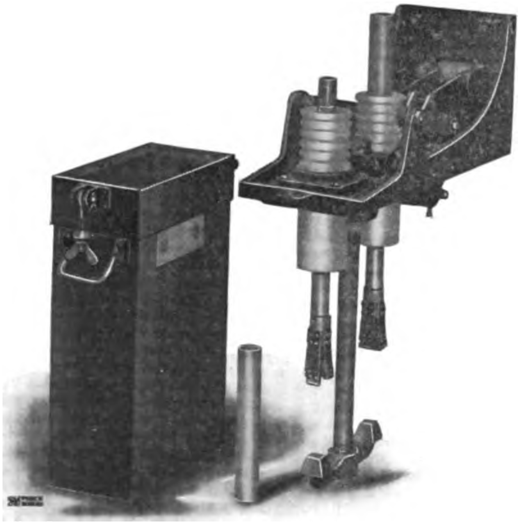


Fig. 3. 300 Ampere, 15,000 Volt, S. P. S. T. Oil Switch

The low tension oil switches are the General Electric Company's standard Type F Form K-4, as shown in Fig. 3, each complete switch consisting of three single-pole single-throw elements operated by a single solenoid. The switches are mounted in fire-proof cells, each pole in a separate compartment, with the solenoids in small sub-cells. The cell doors are made of asbestos lumber with a fire-proof wooden framing, and are pivoted at the top, but have no fastening at the bottom. This light, free swinging construction of cell doors has proven preferable to heavy doors which are fastened tightly to the cells, as the effect of explosions in the cells is temporary only, so far as the door is concerned. The disconnecting switches, bus bars and instrument transformers are mounted on pipe framework above the oil switch cells. As will be seen from the diagram of connections, disconnecting switches are provided on both sides of every oil switch, so that any switch can be inspected, tested and repaired without shutting down any of the circuits.

The high tension oil switches are similar in construction to the low tension switches, and are shown in Fig. 4. These Type F Form K-6 switches are operated in groups of three single-pole elements by solenoids mounted on top of the switch cells. The Form K-6 switch is a top connected device, but in this case the buses and disconnecting switches are necessarily located below the oil switch cells. The adaptability of the switch to different arrangements will be appreciated when it is stated that the only change made in the ordinary layout, with the buses above the switches, was an increase in the size of the cells, this being necessary in order to obtain suitable striking distance from the leads to the ground. Masonry compartments are provided for the high tension bus bars.

Protection against lightning is obtained by the use of a three-phase aluminum cell lightning arrester for each transmission line, these arresters being mounted outside of the station.

The benchboard proper consists of six panels of oiled black slate, the total height, including the instrument section, being 8 ft., 2 in., and the length, exclusive of the swinging bracket, 12 ft., 7 in. Facing the switchboard, the first panel at the left controls the two outgoing lines, the next two panels each control three banks of step-up transformers, and the three panels at the right-hand end control two generators each. The alternating current voltmeters and the synchronism indicator are mounted on a swinging bracket at the right-hand end of the board. The back of the instrument sections and control bench is entirely enclosed by removable grillework doors.

One alternating current ammeter, one field ammeter and one polyphase indicating wattmeter are provided for each generator circuit. The two voltmeters on the swinging bracket are connected to the synchronizing bus in such a way that, when synchronizing, one indicates the voltage of the starting machine and the other the voltage of the bus bars to which the incoming machine is to be connected. At other times the synchronism indicator is disconnected from the synchronizing bus by means of a small snap switch mounted on the swinging bracket; the voltmeters can then be connected to any machine by means of the synchronizing plugs, entirely independent of the synchronism indicator.

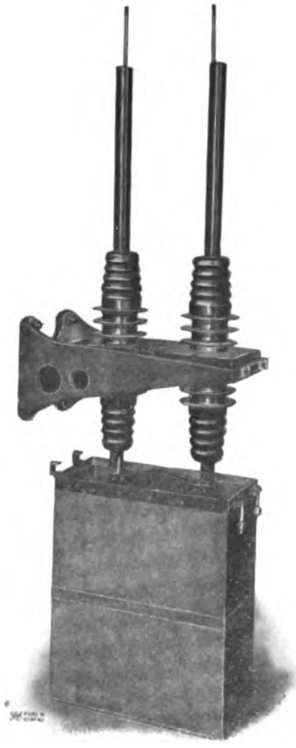


Fig. 4. 100 Ampere, 45,000 Volt, S. P. S. T. Oil Switch

The synchronizing and control switches and the relays are mounted on the control bench. Two synchronizing receptacles are provided for each generator, one being used when synchronizing with bus No. 1 and the other when synchronizing with bus No. 2. Two sets of contacts in these switches are used for synchronizing purposes, but the third set of contacts is connected in series with the closing side of the corresponding oil switch control switch, so that no damage can be caused by the operator becoming excited when synchronizing and trying to close the wrong oil switch. To assist the operator in synchronizing, a governor control switch is provided for each generator circuit, this being a double-pole double-throw reversing switch connected to the governor motor.

The controlling switches for the oil switches and field switches are the well-known twin pull button type, as shown in Fig. 5, which also shows the indicating lamps, or bulls-eyes. One button actuates the "closing" contacts and the other the "opening" contacts, and they are so interlocked that it is impossible to operate both buttons together. An indicator is provided on each switch, which shows green after the control switch has been operated to open the oil switch, and red after it has been operated to close the oil switch. Being a pull button switch, it is impossible to cause trouble by accidental pressure, and, as the contacts are behind the panel, there is no danger to the operator and no chance of accidental short circuits. Severe arcs cannot occur in the control switch on account of a solenoid control relay being used to open and close the closing coil circuit of the solenoid. The use of this relay, which is mounted close to the solenoid, makes it unnecessary to run large control leads to the benchboard. The indicating lamps are connected so that they show the actual position of the main switch—red when the oil switch is closed and green when it is open. If the indicating lamps and the switch indicator do not agree the operator knows that the oil switch has tripped automatically. When this has occurred the control switch indicator shows red and the indicating lamps green. To make the indicating lamps plainly visible from a considerable distance or at an angle, a V-shaped projection is cast on the front of the lens.

Generator field rheostats are mounted below the switchboard gallery and are controlled by combination bevel gear and chain mechanisms, the operating hand-wheels being mounted on pedestals in front of the switchboard. The field switches are solenoid operated and controlled from the benchboard, the same type of control switch and indicating lamps being used as for the oil switches. As stated above, the exciter and field switch panels are of the ordinary vertical type, two sets of bus bars being used. As the field switches are single-pole single-throw, it is necessary to connect double-pole double-throw lever switches in series with them, so that the fields can be connected to either bus.

Mimic bus bars are mounted on the control switch bench and consist of small polished copper bars, which have no electrical connection with any part of the circuit. They show the system of A.C. connections exactly as indicated in Fig. 2, the controlling switches representing the oil switches and nameplates representing the generators, transformers and lines.

The overload relays provided for the generator circuits are single-pole, the secondaries of the current transformers being cross-connected. As the generators are three-wire machines, the third line necessarily carries the resultant current of the other two lines, and full protection is obtained by the use of two current transformers. This connection cannot be used on the transformer panels, as three ammeters are provided for the transformer circuits, and it was consequently necessary to use double-pole relays. On the middle generator panel is mounted the signal relay which is used to ring an alarm bell when any of the oil switches are tripped automatically. This relay is arranged so that the bell continues ringing until the operator releases the relay, and is connected in such a way that it does not operate when the oil switches are opened or closed by the switchboard operator.

Each transformer circuit and each line is equipped with three ammeters. In addition to these instruments there is one ammeter connected in the neutral bus so as to read ground currents. Controlling circuit equipments are similar to those for the generator panels. Synchronizing receptacles are provided for the line circuits but not for the transformer circuits, the receptacles for the line circuits being intended for use when additional generator stations are placed in operation.

In conclusion, attention is directed to the general arrangement and equipment of the board. No panel is at all crowded; control and measuring apparatus is simple; and no superfluous or infrequently used devices are included. The equipment for each circuit is segregated so that there is no confusion in emergencies. Many recent switchboards have been unnecessarily complicated and crowded on account of including elaborate testing equipments or other devices used only at long intervals of time, the designers apparently overlooking the fact that switchboards are primarily intended for constant use in controlling the machines and circuits. Simplicity in operation involves a corresponding simplicity in design and equipment, and insures reliability, which, in the large majority of central stations, is of the greatest importance.

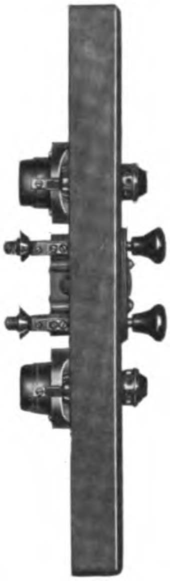


Fig. 5. Twin Pull Button Controlling Switch for Oil Switch or Solenoid Control Circuit

The switchboard described above was designed and built by the General Electric Company of Schenectady, N. Y., to meet the requirements set forth in the Government specifications, and has just been shipped to Arizona. The photographs were taken at the factory, and show the board exactly as it will be installed.

HEATING STAND FOR ELECTRIC FLAT IRONS

By John Liston

The success of the General Electric flat iron is indicated by the fact that there are to-day more than 250,000 of them in actual service for both household and laundry work.

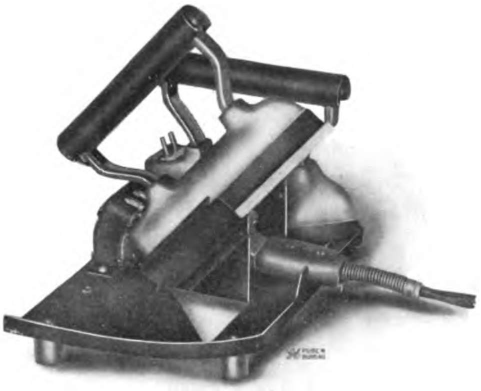


Fig. 1. End View of Electric Flat Iron Heating Stand

While the superiority of the electric flat iron over all other forms is now universally conceded, the fact that the attaching cord is connected to the iron while it is in operation is considered by some to be an obstacle to the most efficient operation. In addition to this, the ordinary electric flat iron must be connected and disconnected by means of a connecting plug, each time it is used, or else the current turned on and off, either at the iron or at the lighting socket, by means of a switch.

Occasionally, due to carelessness or oversight, the iron is not disconnected when it has attained its maximum temperature, and in some cases the current is left flowing when the iron is not in service. This practice results in unnecessary consumption of current and entails higher cost for a given amount of work.

In order to retain all the advantages of electric heating of flat irons, and at the same time obviate the drawbacks enumerated above, the General Electric Company has developed a heating stand for electric flat irons which consumes current only when the iron is being heated. While it has been designed primarily for laundry service, its convenience, and its assurance of economy in current consumption, render it of great value in household work as well. The stand, which is shown in the accompanying illustrations, accommodates two irons and is substantially made. It consists of a sheet-iron base mounted on four composition feet, containing in the center an inclined plane of heavy asbestos board. At the foot of this inclined board is located a composition block protected by sheet-iron and containing flexible phosphor-bronze contacts. On either side of this inclined plane is a shelf, on which the irons are placed when not in service.

The electric connection to the stand is made by means of the ordinary flat iron cord and plug.

When in service, the iron to be heated is placed on the inclined plane of asbestos board, down which it slides due to gravity. The terminals on the iron automatically engage the flexible phosphor-bronze contacts in the stand and complete the circuit.

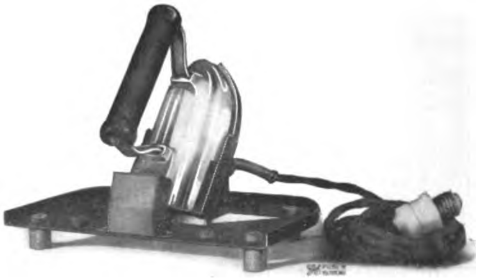


Fig. 2. Front View of Electric Flat Iron Heating Stand

The iron heats rapidly, as radiation from the flat surface is prevented by the asbestos board. When in circuit the contacts on both the iron and stand are thoroughly protected, so that there is no possibility of either a short circuit or injury to the operator. The use of this stand obviates the necessity for switch, plug or cord; and when the iron is removed, the circuit is instantly interrupted so that no current is consumed except while the iron is being heated. The economy resulting from the use of this stand is particularly noticeable in laundries, where the cost of current not consumed in actually turning out work is an important and, at present, indeterminate factor in operating expense.

The fact that the circuit is completed only while the irons are heating renders feasible the permanent connection of the stand, and permits ironing to be accomplished with all the advantages inherent in electric heating, with none of the disadvantages of the ordinary electric flat iron.

ROTARY CONVERTERS*

PART VII

BY ERNST J. BERG

Power-factors

The power-factor at the rotary is found directly from Fig. 21, as

$$\cos \omega = \frac{i}{I} = \frac{i}{\sqrt{i^2 + i_1^2}}$$

The power-factor at the generator is the ratio of the energy output (which is the rotary output plus the line loss) to the volt-amperes at the generator.

It is therefore equal to

$$\cos \phi = \frac{ei + I^2 r}{e_0 I}$$

These two power-factor curves corresponding to Fig. 22 are plotted for the case of 10 per cent. resistance, 20 per cent. reactance and 5 per cent. over compounding. It may be seen that with leading currents (above 300 amperes), the power-factor is decidedly better at the generator than at the rotary. The full load power-factor at the converter is only 86 per cent., and the wattless current is leading.

As stated above, in these calculations and curves it has been assumed that the wattless lagging current at no load is the same as the wattless leading current at full load.

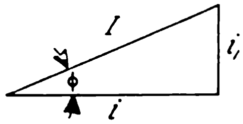


Fig. 21

However, the heating of the armature at full load, and especially at overloads, is very considerable with this adjustment; therefore all rotaries do not permit of such operation.

To favor the rotary in regard to armature heating, the power-factor should be of unity value at full load. Under this condition, referring to equations 12 and 13, we get the following equations:

$$e_n = -i_n x + \sqrt{e_0^2 - i_n^2 r^2}$$

and

$$e_f = -Cr + \sqrt{e_0^2 - C^2 x^2}$$

Let $e_f = k e_n$, and solving both equations for e_0^2, at the same time neglecting terms containing $(r^2 + x^2)$ as a factor (this term being small), we get:

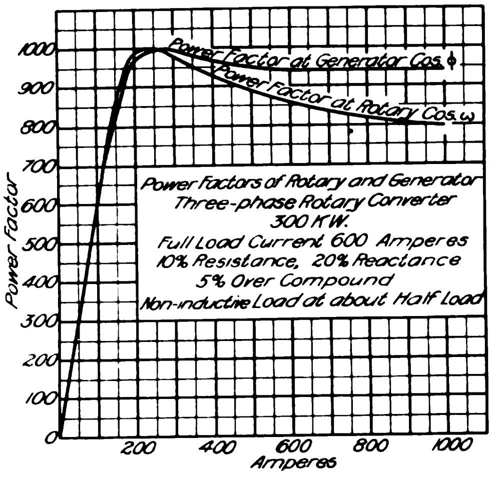


Fig. 22

$$i_n = \frac{e_n (k^2 - 1) + 2kCr}{2x} \qquad (18)$$

We have previously shown that:

$$i_n = \frac{C}{1.15R} (F_0 - F) \qquad (19)$$

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* For Part VI of this article see July REVIEW.

and $$i_f = 0 = \frac{C}{1.15R}\left[k\,(F_0-F) - CpT\right] \tag{20}$$

thus, by solving equation 20, we get:

$$k\,(F_0-F) = CpT, \text{ or } T = \frac{k\,(F_0-F)}{Cp} \tag{21}$$

From equations 18 and 19 we get:

$$\frac{e_n\,(k^2-1)+2kCr}{2x} = \frac{C}{1.15R}\,(F_0-F)$$

$$\frac{1.15R}{2XC}\left[e_n\,(k^2-1)+2kCr\right] = F_0-F$$

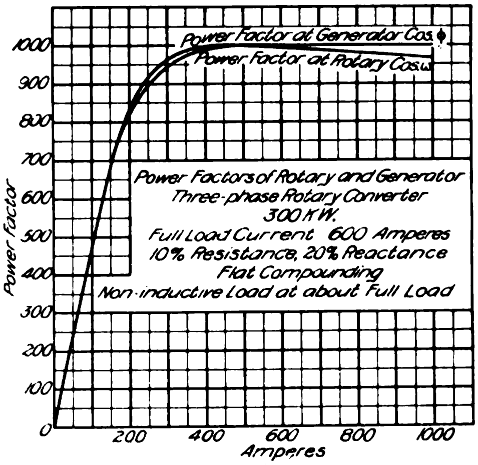

Fig. 23

or $$F = F_0 - \frac{1.15R}{2XC}\left[e_n\,(k^2-1)+2kCr\right] \tag{22}$$

and T as shown in equation $27 = \dfrac{k\,(F_0-F)}{Cp}$

Numerical Instances

Assume that the 300 kw. rotary is operated on a system of 10 per cent. resistance and 20 per cent. reactance, and that it has a flat compounding. What should be the relation of shunt to series field, and what are the power-factors at the rotary and at the generator? We have, as in the previous case:

$R = 3820$
$F_0 = 6300$
$p = .945$
$C = 470$
$e_n = 369$
$r = .0455$
$x = .091$
$k = 1$

Thus, referring to equation 22:

$$F = 6300 - \frac{1.15 \times 3820 \times 2 \times 470 \times .0455}{2 \times .091 \times 470} = 4100$$

and $$T = \frac{6300-4100}{470 \times .945} = 4.97 \text{ (5 turns).}$$

Substituting these values in equation (July, 1908, REVIEW, page 46):

$$i_1 = \frac{C}{1.15R}\left(\frac{e}{e_n}\,(F_0-F) - ipT\right)$$

we find the wattless current, corresponding to any energy current i, to be:

$$i_1 = \frac{470}{1.15 \times 3820}\left[2200 - 4.72i\right]$$
$$= 235 - .505i \tag{23}$$

The generator voltage, which is kept constant at all loads, is obtained from the no load conditions by referring to equation 9:

$$e_0 = \sqrt{(369 + i_n \times .091)^2 + i_n^2 \times .0455^2} \tag{24}$$

In this case, referring to equation 18:

$$i_n = \frac{2 \times 470 \times .0455}{2 \times .091} = 235 \text{ amperes,}$$

which, when substituted in equation 24, gives

$$e_0 = 390 \text{ volts.}$$

The actual voltage at the rotary is found from equation 10, as:

$$e = -(ir + i_1 x) + \sqrt{e_0^2 + 2ii_1 rx - i^2x^2 - i_1^2 r^2}$$

The power-factors at generator and converter are shown in Fig. 23. It is seen that with this adjustment of field the power-factor at the generator is practically unity from full load up to 50 per cent. overload. At half load, however, the power-factor is only 92 per cent., and the current taken by the converter is lagging.

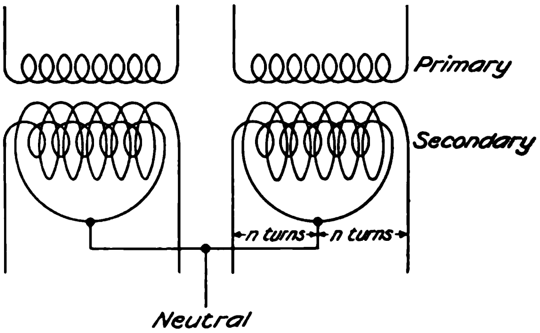

Fig. 24

Transformer Connections for Rotary Converters

The arguments for and against the Y-delta, delta-delta, Y-diametrical, two-phase, three-phase transformation, etc., apply equally well to rotary converters as to other electrical machinery; therefore it seems unnecessary to discuss them here.

When, however, a converter is used in a three-wire direct current system, with the neutral brought from the transformers, certain limitations in choice are imposed, these limitations being due to the presence of direct current in the transformers.

It is evident that only such connections may be used as will produce a resultant direct current m.m.f. of zero value in each transformer.

This is possible if the windings are arranged with very good mutual induction, and when the direct current can traverse one-half of the winding in one direction and the other half in the other direction, with a resultant magnetism of practically zero value.

The standard connection is feasible for two-phase converters if the two halves of the secondary windings are properly interlinked. This connection is diagrammatically shown in Fig. 24.

With three-phase converters, two connections are possible, the T-connection (Fig. 25) and the "distributed Y" (Fig. 26).

Both have the disadvantage of using material inefficiently, and require 15 per cent. more transformer capacity than the rated capacity of the converter. The T-connection has the advantage that it requires two transformers only.

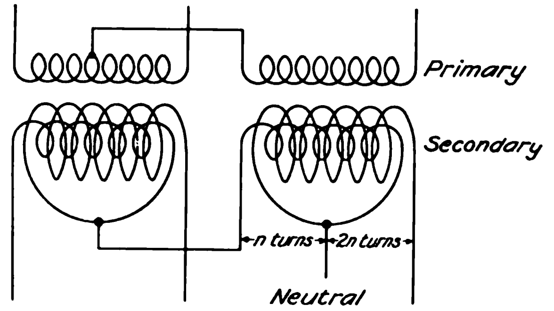

Fig. 25

The distributed Y has the advantage that the high potential connection can be delta connected; therefore, the system is better balanced.

Three Y-connected transformers, or three transformers with their low potential sides Y-connected, are not permissible, since with this connection there is a magnetizing effect of the direct current superimposed upon that of the alternating current, which, even with a very slight direct current, saturates the transformer.

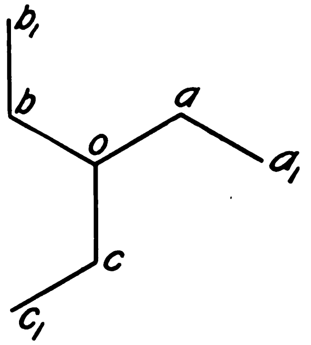

Fig. 26

Assume, for instance, that the magnetizing current of the transformer is 6 per cent. of full load current, and further, that the neutral current is 12 per cent. of full load value; therefore, one-third of 12 per cent., or 4 per cent. of the full load direct current flows through the transformer winding. The maximum value of the flux is the determining value, and since this value of the flux is proportional to the maximum value of the current, and since, furthermore, the maximum value and effective value of the direct current are the same, while the maximum value of the alternating current is $\sqrt{2}$ × times the effective value, it follows that the transformer maximum flux is increased $\frac{6\sqrt{2}+4}{6\sqrt{2}} = 1.47$ when the normal value is taken as unity. Thus the density is increased 47 per cent. An increase of flux of 47 per cent. will, in almost all transformers, saturate the iron. Thus, not only will the core loss be very much increased, but the magnetizing current will often become prohibitive.

We must therefore conclude that the Y connection can not be used, even for the very slightest unbalancing.

With six-phase converters the neutral can be brought from the neutral of the three diametrically connected secondaries if there is good mutual induction between the two halves of the secondary winding.

AUTOMATIC CONTROL APPARATUS, HUDSON TERMINAL BUILDING

By C. D. Knight

The Hudson Terminal Building, which is the largest and best equipped building of its kind in New York City, has recently been completed. In order to save labor, an effort was made to operate all the electrically driven machinery automatically, wherever possible.

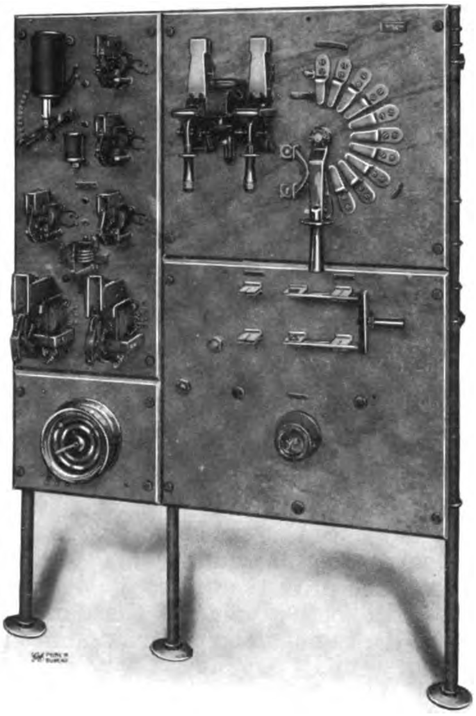

Fig. 1. Combination Automatic and Manual Control Motor Panel for Controlling 85 h.p. Motor Driving Air Compressor

With this end in view, the engineers of the General Electric Company were called upon to make recommendations, with the result that the Company was awarded the contract to supply the various motors and automatic controlling apparatus necessary to fill the requirements. The following apparatus was supplied:

One 85 h.p. motor, with automatic self-starter operated by a pressure gauge controlling an air compressor.

Three 30 h.p. motors, with automatic self-starters operated by vacuum gauges.

One 30 h.p. motor for boiler feed pump.

One 5 h.p. motor for sump pump.

The last two motors were equipped with automatic starters, which were operated by float switches.

One 20 h.p. motor for brine pump.

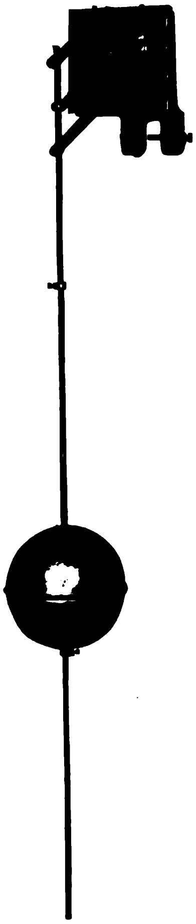

Fig. 2. Float Switch, Controlling Automatic Starters for Motor-Driven Pumps

One 5 h.p. motor for ammonia pump, with automatic starters operated by pressure gauges.

Three 75 h.p. motors for ventilating plant, controlled by an SB panel; hand-operated.

All of the automatic starters are mounted on marble panels, which, in addition, are equipped with hand starters so interlocked with the automatic that but one or the other can be operated at a time. This system acts as a safeguard in case anything happens to the automatic devices. It also enabled the designers to introduce some field control in order that the motors, in case of emergency, can be speeded up.

Those automatic starters which are controlled by the variation of pressure have the pressure gauges mounted directly on the panel. They are set for any given minimum and maximum pressures required. When the needle reaches the low pressure point, contact is made and the relay energized, this in turn energizing contactor No. 1 of the self-starter. As soon as the contactor closes, the master solenoid is energized, causing the arm to pull up over a series of buttons. The action of this arm is controlled by a dashpot which introduces the time element on the acceleration of the motor. As the arm passes over the buttons, the remaining contactors are energized one after the other, each one cutting out a step of resistance until the motor has come up to speed and the last contactor is in place. As this last one closes, it opens the circuit of the master solenoid and that of all the contactors with the exception of the two lower ones on the panel, which are designed for continuous service. These are the only two contactors which are in circuit all the time, and which require any energy while the motor is running. This means quite a saving in current, and is a feature used only on General Electric controllers.

When the high pressure point has been reached, the needle of the pressure regulator makes contact and short circuits the small relay, which in turn de-energizes the two contactors, opening the main line switch and causing the motor to shut down. This cycle of operation is kept up continually, so long as the main line knife blade switch in the panel is closed.

In cases where float switches are used, the difference in water level opens and closes them, they in turn controlling the automatic starters through the same cycle of operation as previously explained for pressure regulators.

One of the principal features of this installation was the exceedingly quick deliveries which were made. The final specifications on the apparatus were received January 22, 1908, and practically complete shipments were made by March 15th.

VENTILATION OF STEAM TURBINE STATIONS

By W. J. Foster

The concentration of generating units of immense capacities into the space mechanically permissible in steam turbine driven sets, makes necessary the providing of a suitable carrier for the heat that represents the losses of the generators. It may be assumed that the heat energy which must be removed from the generator ranges from 4 per cent. of the output, for a 10,000 kw. unit, to 6 per cent. for a 500 kw., when operating at rated loads.

Let us consider the problem of removal of this heat from a unit that is generating a maximum of 10,000 kw. Assuming the total losses, or the heat to be removed, to be 4 per cent., we have 400 kw. as the energy to be dissipated. In accordance with common practice regarding the allowance per square inch for radiation of heat from a surface into still air, for a rise of 40° C. we should have an area of approximately 7,000 square feet. Therefore, if we consider several of these generators located in the same station, each arranged to thoroughly stir up and mix the air within its own territory, but not permitted to take any air from outside its own allotted space, the units should be installed with not less than 80 ft. between centers.

Now, when we consider the economy to be derived by installing generating sets so that they will occupy a small amount of floor space; the possibilities, so far as mechanical problems are concerned, of locating the largest steam turbine units within such a space; and the fact that good engineering requires the best possible removal of heat from the generators, and the best possible retention of heat in steam pipes and the turbine itself; it becomes evident that the problem of the circulation of large quantities of air is fundamental in station designing.

It is the purpose of this article to throw out suggestions that may be helpful in providing efficient circulatory systems. Steam turbine stations are of two classes, considered with reference to the boilers; *viz.*, forced draught and natural draught. Where forced draught is used, the station may be designed, with reference to the air circulation in generators, in three different ways, all of them having in view the passing of air through the generators before it reaches the fire boxes under the boilers.

1. Definite piping from out of doors to the generator, and from generator to the blowers supplying forced draught.
2. Definite piping from out of doors to the generator, exhausting from the turbine room by the blower supplying forced draught.
3. Definite piping from generator to blower, with sufficient air inlets to station so that the air may be exhausted from dynamo room to boilers by way of generators.

Where natural draught is used, there is no system of exhaust in the boiler room to take the air from the dynamo room. Generators are almost invariably constructed so that their own rotors supply sufficient blower effect to circulate the air needed for cooling. In some cases a separate fan or blower may be mounted on the same shaft as the rotor proper, assisting in the circulation. The same three methods of piping to and from the generator may be arranged for as in connection with forced draught. In passing through the generator, an elevation in temperature of the air of from ten to twenty degrees should be aimed at. It is a good plan to supply air in such quantities that at maximum overload the temperature of the outgoing air will not be more than twenty degrees above that of the ingoing. In a well-designed station, it will always be possible to have the temperature of the ingoing air not more than two or three degrees higher than the outdoor temperature. At the same time, things should be arranged so that the temperature of the ingoing air may be kept many degrees above that of the outdoor air. In cold weather it is a good plan to draw part of the air from the dynamo room itself, taking such proportions from each source as will make the temperature of the mixture somewhere between ten and twenty degrees centigrade. In extremely cold weather, if all the air were drawn from out of doors, it might happen that the temperature of the air coming out of the generator would be below that which is comfortable for operatives, as well as that at which the dynamo room would ordinarily be maintained. With the latter condition a condensation of water would result on the surface of the generator; this would be objectionable.

As to the proper quantity of air to circulate through a generator, there should be provided for machines of from 5000 to 10,000 kw., approximately three cubic feet per minute per kilowatt of maximum output. For generators as small as 500 kw., five cubic feet per minute per kilowatt maximum output should be supplied. For intermediate sizes, the allowance should be proportioned in accordance with the above quantities for the largest and smallest sizes.

With regard to the size of ventilation pipes, it is recommended that the cross-section be such as to prevent a higher speed of air than 3000 feet per minute, and preferably, to obtain a speed of 2000 feet, or less. Where definite piping is provided to the generator alone, and the air is thrown out into the dynamo room, sufficient outlets in the way of ventilators, open windows or doors, should be provided. Of course, in the coldest weather these outlets will be reduced to a small fraction of the maximum. It is recommended that they be of such size as to limit the speed of the outgoing air to 500 feet per minute. This calls for an area of sixty square feet for the outlet vents, for a generator with a maximum output of 10,000 kw. requiring 30,000 cubic feet per minute.

While definite piping direct to the generator is strongly recommended, it is not always necessary. It is possible to lay out a turbine station for vertical shaft sets in such a manner as to allow the units to be placed with distances between centers so small as to be limited to mechanical considerations only, at the same time keeping the temperature of the ingoing air within a few degrees of that of the outdoor air. This can be accomplished by placing the several turbine units in a row, close to the side of the building, with inlets of large area at the proper elevation with respect to generators. The generators should then be arranged to draw the air in at one point only, with a fairly high speed, and to emit it at a remote point, diametrically opposite if possible. In the case of a vertical shaft unit, it is generally more desirable to have the intake at the top than at the bottom.

It is undoubtedly possible to obtain a good design of station without definite piping to or away from the generator, by arranging ventilating ducts of sufficient cross-section in the walls, and with intakes either in the side of the building, in the basement, or in cupolas on the roof, with openings in the wall directly above the top of the generator. Here, again, the units should be installed quite close to the wall. The air inlet in the generator should be on the side towards the wall, directly opposite the opening from wall to room.

ARC LIGHTING SYSTEM OF PORTLAND, OREGON

By B. C. Coldwell

During the past three years the arc lighting system of the city of Portland, Oregon, has been entirely renovated. The old system, consisting of 9.6 ampere Thomson-Houston direct current series arc lamps, deriving current from 100-light Excelsior arc generators driven by means of direct connected D-62 600-volt motors, has given way to a modern installation of General Electric magnetite lamps supplied with current from constant current transformers and mercury vapor rectifiers.

The old arc circuits were reconnected for the accomodation of the new lamps, each circuit being arranged for approximately 75 lamps, this being the load for which the rectifier sets were designed. The constant current transformers are connected to the high tension feeder system of the Portland Railway Light and Power Company, which operates at a potential of 10,000 volts and a frequency of 33 cycles.

The General Electric Company has made many changes in the mechanism of the magnetite lamp during the transition period, and as all of the improvements have been applied to the lamps in Portland, there are not, at the present time, any of the original type of lamps on the circuit. The mercury vapor rectifier tubes have likewise been greatly improved, and many types of tubes have been tried on the Portland ciruits.

A considerable amount of difficulty was experienced with the early lamps; there was not sufficient draft, with a consequent clogging of chimneys and a deposit of oxide on the globes. A better designed fume box has remedied this. The early swinging upper electrode, consisting of a starting and burning sector, has given way to the verticle electrode, which gives much better results. All cracking of globes, due to hot metal being thrown from the swinging electrode, has been obviated by the use of the later electrode.

The lower electrode, or magnetite stick, as now manufactured is giving excellent results. With the original one, there was at times a formation of slag which prevented the starting of the arc until the slag was broken. Some trouble was occasioned by the blowing out of the arc by air currents over the top of the globes. This has been done away with by putting a piece of felt on the pan for the globe to cushion on.

The lamp gives an excellent white light and possesses that characteristic most valuable to an arc lamp for use in lighting streets; namely, its maximum candle-power is in a direction only a few degrees below the horizontal. This gives it penetrating quality, especially valuable in a city with many trees and much heavy foliage.

The magnetite sticks burn on an average about 170 hours for one trimming. The maintenance expense of the lamps is very much less than that of the old Thomson-Houston lamp, and one repairman is doing all of the repair work on the entire installation of about 1600 lamps.

The tub transformers used are of the oil-cooled constant current type. Current from these transformers passes through the rectifier tube and then to the circuit. When the rectifier system was first put into operation, a single tube was used with each transformer. It was found, however, that a single tube did not work satisfactorily on a circuit with 75 lights, and therefore two tubes have been installed in place of the one, the voltage on each tube being thereby cut down one-half. The tubes are mounted one above another on the top of a plug-board panel, and current is carried to them from the transformer by means of cambric insulated cable.

The first sets installed had a reactance for the rectified current, and also two alternating current reactances, the latter having since been eliminated.

When the tubes were first installed, a good deal of trouble was occasioned by static on starting, but this has now been practically overcome—experience has shown how it should be handled. Temperature and weather conditions affect the operation of tubes somewhat, and it is therefore necessary that air which is used for cooling purposes be given considerable attention. The operators are now well posted on all conditions affecting the operation of tubes, and can tell at a glance whether a tube is running too cool or too hot, and just what steps should be taken to correct the difficulty. The vacuum in an old tube is not so good as in a new one, and in order to get results, it must be watched a little more closely than the new tube, especially when starting. There is nothing about the operation that can not be readily understood by any station operator.

The average life of the tubes is now about 1100 hours. The record tube of the plant has already burned 3070 hours and is still operating satisfactorily. The tubes punctured per lamp per month on the Portland circuits is .008 tubes. For blowing purposes for the two-tube outfits, we find 5.5 watts are required per lamp.

AN ISOLATED PLANT, 3-WIRE SWITCHBOARD

By D. H. Plank

The General Electric Company has recently completed a switchboard for the United States Soldiers' Home, Washington, D. C., which, while following the generally accepted design for an isolated plant board controlling combined lighting and power service, embodies several unique features of construction.

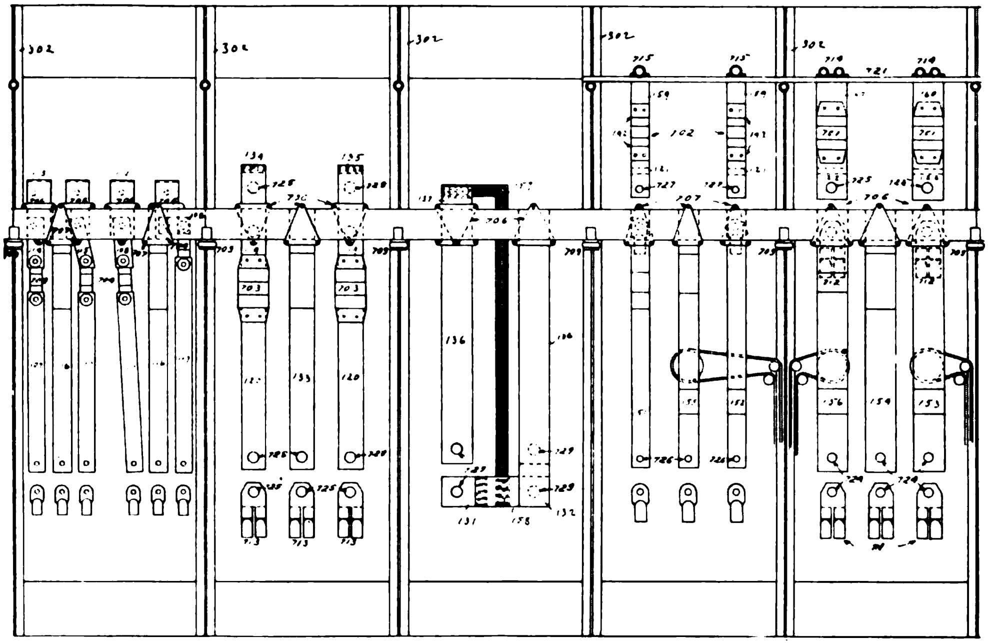

Fig. 1. Five Panels of Switchboard

The switchboard is designed to control two 300 kw., 125/250-volt, direct-connected, turbine-driven generator sets, (each consisting of two 150 kw., 125-volt, D.C. compound wound generators, designed for three-wire operation) and one 150 kw., 125/250-volt, direct-connected, turbine-driven, three-wire compound wound D.C. generator with double commutator. The generating sets of both capacities are connected to horizontal Curtis steam turbines operating at 1500 and 2000 r.p.m. respectively. The distribution circuits consist of five 125/250-volt, three-wire feeders, one of 2000 amperes and four of 1000; and five 250-volt, two-wire circuits, one carrying 1000 amperes and the remaining four 500 amperes each.

The switchboard is made up of eleven blue Vermont marble panels resting on a black marble subbase and surmounted by an ornamental marble cornice. Fig. 1 is a front view of five panels of this board as assembled in the factory before shipment. A separate panel is provided for controlling each of the generating sets, and two others for controlling the 2000-ampere, three-wire and the 1000-ampere, two-wire feeder circuits. For the remaining feeders four panels have been supplied, each designed for controlling two circuits. Between the generator and feeder panels a total output or station panel is furnished, which contains a three-wire integrating wattmeter, curve tracing voltmeters, and a non-magnetic clock. At the left-hand end of the board, on a swinging bracket, are two illuminated dial voltmeters, one of which is connected to read the voltage across the bus bars, while the other is arranged for reading the voltage across each generator. To the left of the generator panels is a blank panel which will contain the equipment for controlling a fourth generating set.

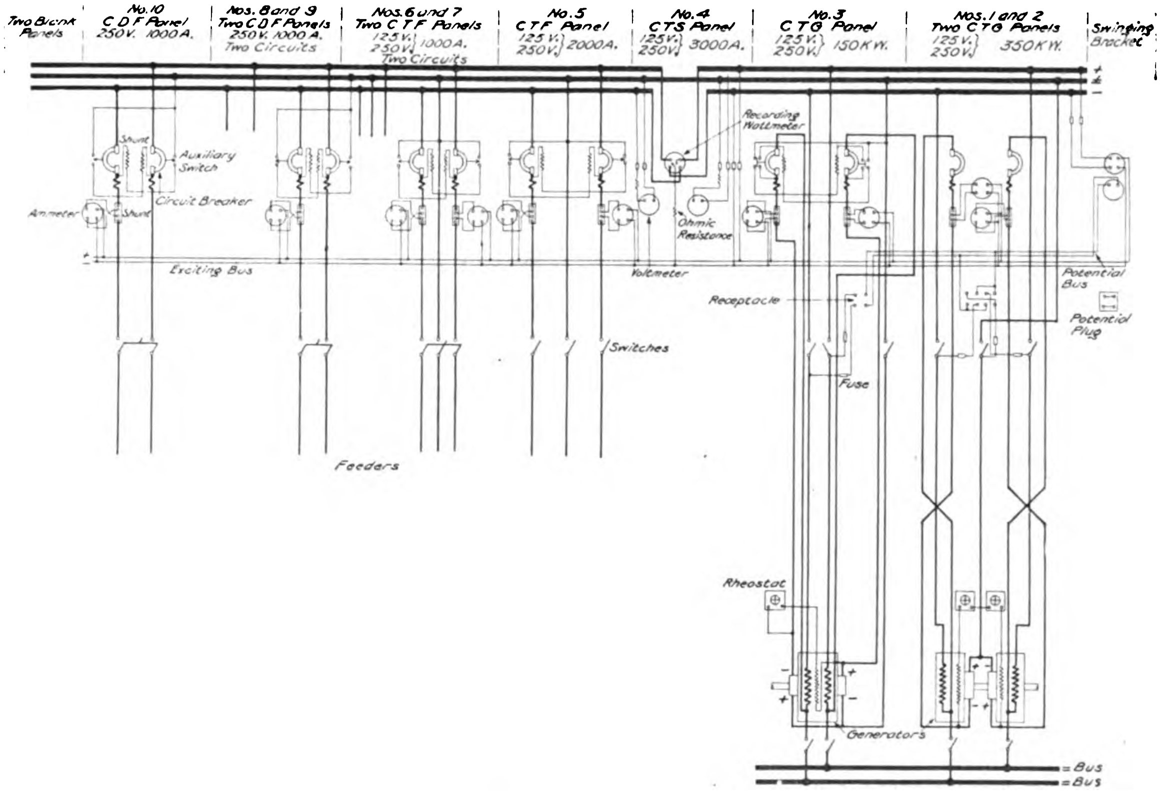
Two Blank Panels
No. 10 C D F Panel 250V. 1000A.
Nos. 8 and 9 Two C D F Panels 250V. 1000 A. Two Circuits
Nos. 6 and 7 Two C T F Panels 125 V. 250 V. 1000A. Two Circuits
No. 5 C T F Panel 125 V. 250 V. 2000A.
No. 4 C T S Panel 125 V. 250 V. 3000A.
No. 3 C T G Panel 125 V. 250 V. 150 K.W.
Nos. 1 and 2 Two C T G Panels 125 V. 250 V. 350 K.W.
Swinging Bracket
+
±
−
Shunt
Auxiliary Switch
Circuit Breaker
Ammeter
Shunt
Recording Wattmeter
Ohmic Resistance
Exciting Bus
Voltmeter
Receptacle
Potential Bus
Potential Plug
Switches
Fuse
Feeders
Rheostat
Generators
= Bus
= Bus

Fig. 2. Wiring Diagram

The connections of the various panels are shown in Fig. 2; in all essential features these follow the general practice for this class of service. It will be noted by referring to this figure, that for controlling each of the generating sets, two ammeters and two circuit breakers have been provided, one for the positive and one for the negative side of the circuit. The positive, negative, and the neutral switches are mounted directly on the switchboard panels; the equalizer switches, however, are mounted on pedestals located near the machines. The circuit breakers on the three-wire, single unit generator panel are furnished with shunt trip coils and auxiliary switches which are so arranged that when one circuit breaker trips, the other will also be tripped. For three-wire machines this feature is very desirable, as it affords protection against the excessive loads which would otherwise be thrown on the neutral in event of the opening of a circuit breaker connected to one side of the circuit. The circuit breakers protecting those sets that consist of two separate generators connected in series, are not provided with these interlocking attachments, as in this case the neutral will carry the full load of one side of the system continuously. Potential receptacles and plugs are supplied for connecting one of the voltmeters on the swinging bracket to read the voltage on any generator.

For controlling each of the three-wire feeders a circuit breaker and an ammeter have been connected in each of the outside leads in series with lever switches which open these leads. A third lever switch has also been installed for opening the neutral. The circuit breakers on these circuits are equipped with interlocking attachments similar to those on the three-wire generator circuits. For controlling each of the two-wire feeders, two circuit breakers with interlocking attachments have been connected in the positive and negative leads, the positive side of the circuit also including an ammeter. A double-pole switch has been installed in series with these circuits.

The indicating instruments are of the Thomson astatic type, the instruments on the generator panels having illuminated dials, while those on the feeder panels are of the feeder type. All the instruments have electro-magnetic field magnets except the voltmeter used for reading the voltage of the generators, which is supplied with a permanent magnet. The finish of all instruments is dull black with the raised portions copper-plated.

General Electric carbon break circuit breakers are used throughout. On the circuits where the capacity does not exceed 1200 amperes the Type C, Form P circuit breakers have been furnished, and Type C, Form K where larger capacities are required. As these are highly finished, with copper parts polished and lacquered and all other parts dull black, they add very much to the fine appearance of the switchboard. The circuit breakers are all located near the tops of the panels, an arrangement which precludes all possibility of the arc produced by the opening of the breaker damaging any of the other apparatus or injuring the switchboard attendant. The switches are the well-known General Electric Type L, Form D-12 switches, which are standard for this class of service. Both switches and circuit breakers were selected on account of their ability to meet the exceptionally severe heating guarantees required by the Government specifications.

All connections for the main circuits on back of the switchboard are made of bare rectangular copper bars, the current density in no bar exceeding 600 amperes per square inch. The method of making these connections is illustrated in Fig. 3. Particular attention is called to the symmetrical arrangement of the bars and the ample clearances—two points which were given special consideration in working up the design. The connections for the voltmeters and for the exciting coils of the instruments are made of No. 12 rubber insulated wire with flame-proof covering, and are held in place with insulating cleats. Where the main connections are taken from the bus bars, clamps have been used. This construction furnishes a more flexible arrangement than a bolted connection and does not interfere in any way with the conductivity of the bus at the point of junction.

Fig. 4 shows an end view of the board and illustrates the method of bringing the generator leads to the panels.

When installed, the space behind the switchboard will be closed by ornamental grillework and panels, with suitable doors for obtaining access to the rear of the board when necessary. A complete air blast system will also be installed, with frequent outlets along the base of the switchboard, both in front and rear, to which a hose can be attached for removing any dust and dirt that may collect on the switchboard parts.

NOTES

Mr. H. E. Bussey has recently been appointed Engineer of the Atlanta office of the General Electric Company.

* * *

Arthur Russell, an employe of the British Thomson-Houston Company, Ltd., and a member of the B. T. H. Athletic Club, won the 3,200 metre steeplechase at the Olympic Games, recently held in London.

* * *

Mr. W. J. Davis, Jr., has been appointed Engineer of the San Francisco office of the General Electric Company, in charge of engineering work on the Pacific Coast.

Mr. Davis entered the employ of the Thomson-Houston Company at Lynn in 1892, having graduated from the Rose Polytechnic Institute in the same year. In 1895 he moved to Schenectady and entered the testing department of the General Electric Company, where he remained until 1898. He was then transferred to the Railway Engineering Department, with which he was connected at the time of his appointment.

Mr. Davis succeeds Mr. J. A. Lighthipe as Engineer of the San Francisco office.

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1815

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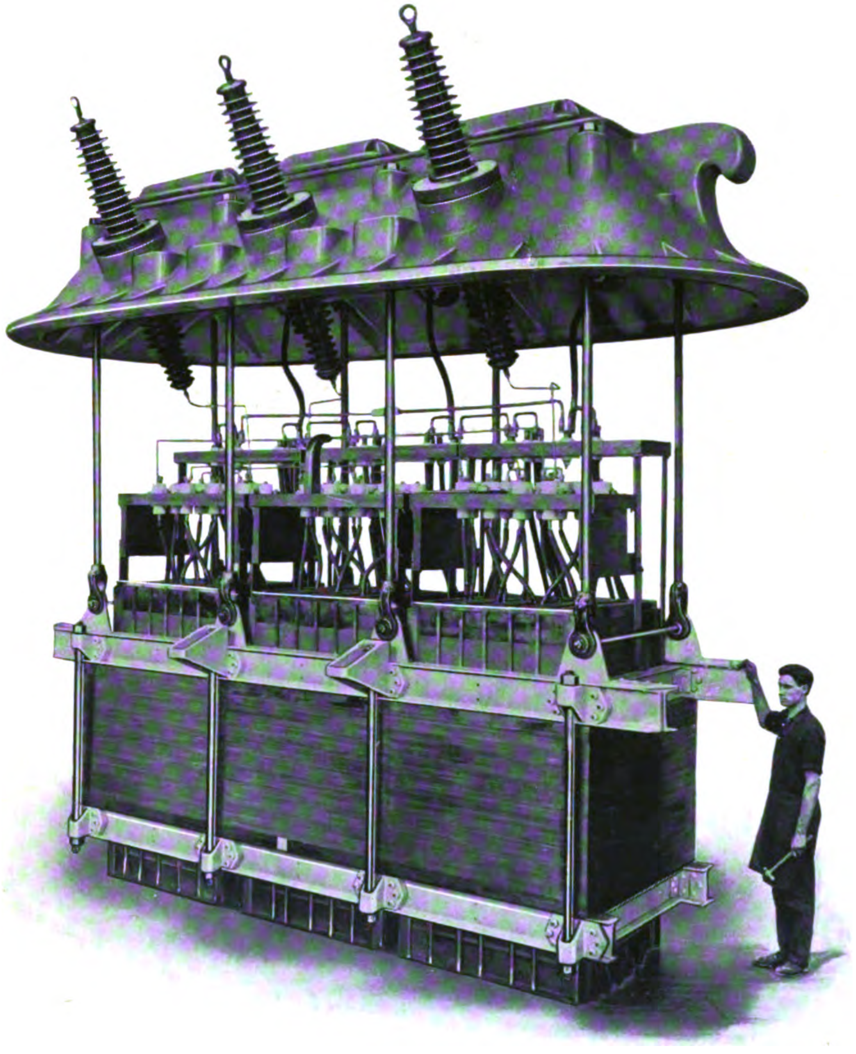

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(See Page 169)

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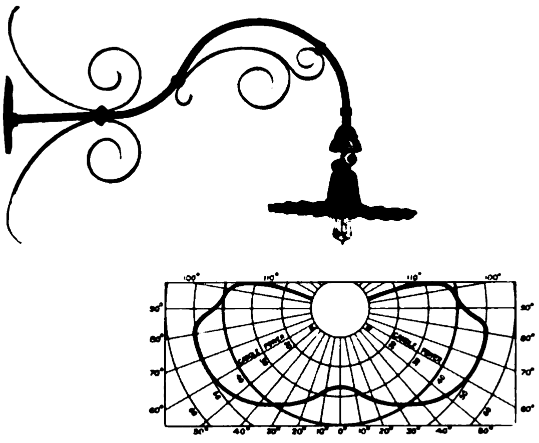

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GENERAL ELECTRIC REVIEW

VOL. XI, No. 4 OCTOBER, 1908

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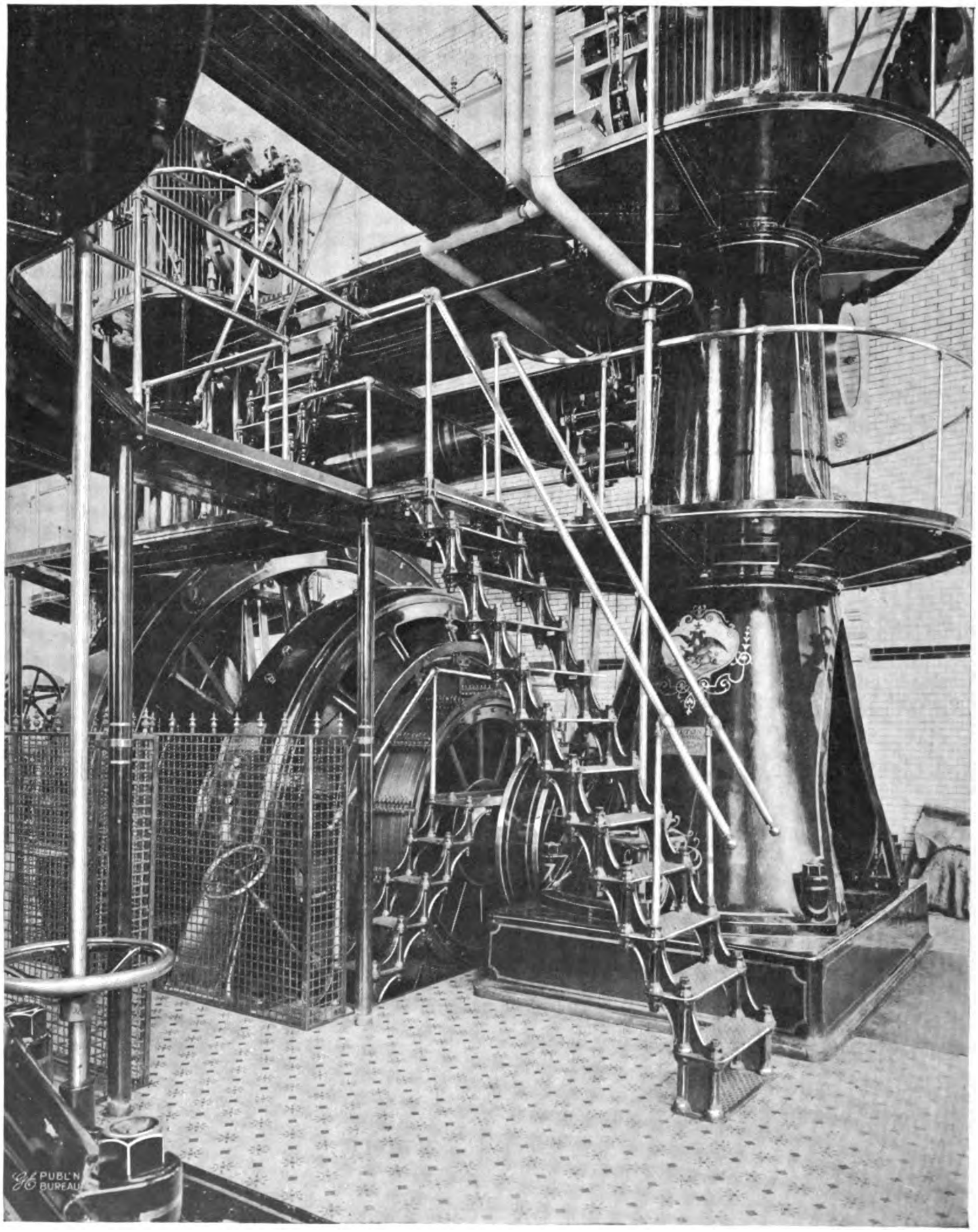


500 Kw. Generator, Power House No. 1, Anheuser-Busch Brewing Association

(See page 180)

GENERAL ELECTRIC REVIEW

AN OUTLINE OF THE TRANSFORMER DEPARTMENT OF THE GENERAL ELECTRIC COMPANY, AT PITTSFIELD, MASS.

By W. A. Hall

Fig. 1. Foundry

THE transformer business of the General Electric Company assumed such proportions more than a year ago, that it was found necessary to materially increase the facilities for the manufacture of this product. It was believed this could be best accomplished by making use of the newly acquired plant of the old Stanley G. I. Manufacturing Company at Pittsfield, which offered many advantages for this work. In the midst of the Berkshires and in the Housatonic Valley, so long favorably known as an active section for miscellaneous manufacture of established reputation, the site presents unusual opportunities for the acquisition of skilled labor of American extraction.

The facilities for transformer manufacture offered by this plant were first utilized as a nucleus about which was developed a plant for manufacturing the small standard lighting transformers. As the work progressed, to keep pace with the growth of business, the advantages of concentrating at this point practically all of the Company's transformer work soon became evident, and it was therefore determined to collect all the work at this plant as rapidly as circumstances would permit. So far had this movement advanced, that on September first of last year, the headquarters of the Lynn Transformer Department were transferred to Pittsfield. Gradually the manufacture of the larger apparatus was moved from Schenectady, until at the present time substantially all of the Company's transformer work is established at Pittsfield in one organization; the exceptions being constant current and switchboard transformers, which, on account of their connections with the arc lamp, and meter and instrument departments respectively, were considered best located in their present intimate relations with those departments with which they co-operate.

A better understanding of the resulting plant may be had from Fig. 2, which shows a general plan of the principal buildings of the Transformer Department. It will be noted in the first place, that it is located on the main line of the New York Central R. R., over which is a heavy steel bridge, formerly a public thoroughfare, but now the property of the Company. This leads to the south side, which contains the power house, iron foundry, the building in which moulded insulations are made, the dry kiln, and the general industries of the plant not intimately associated with the transformer interests. By this railroad passing directly through the plant, and the accessibility nearby of both the New York, New Haven and Hartford, and the Boston and Maine R. R., excellent facilities for obtaining raw material and shipping completed apparatus are afforded.

In establishing this new plant at Pittsfield, every effort has been made to make it as far as possible a decentralized and self-contained department. To this end there have been concentrated under one roof all of the various phases of the work that can be thus advantageously disposed, including in this intimate relation facilities for performing a variety of work is confined to the group of buildings combined in one large structure.

The general scheme of the buildings containing the department is as follows: One large building (Fig. 3), 600 by 185 ft., containing three bays, extends northward at approximately right angles to the railroad. At right angles again to this is a somewhat smaller and lower structure of saw-tooth construction, forming with the larger building a manufacturing space exclusively for work not associated with the ordinary transformer plant. Since the noise of the tank shop, the dust and noise of the carpenter shop, and the heat and dirt of the annealing and moulding rooms cannot, for obvious reasons, be grouped with the processes of winding, insulating and assembling transformers, these component parts of the work have been favorably located in adjacent buildings. With these exceptions then, the transformer work, broken only by the fire walls which divide it into several component sub-departments. About the central building are grouped others devoted to the handling of sheet steel punchings, as well as the carpenter and pattern shop, the brass foundry, the tank shop, the storage building and the physical and chemical laboratory.

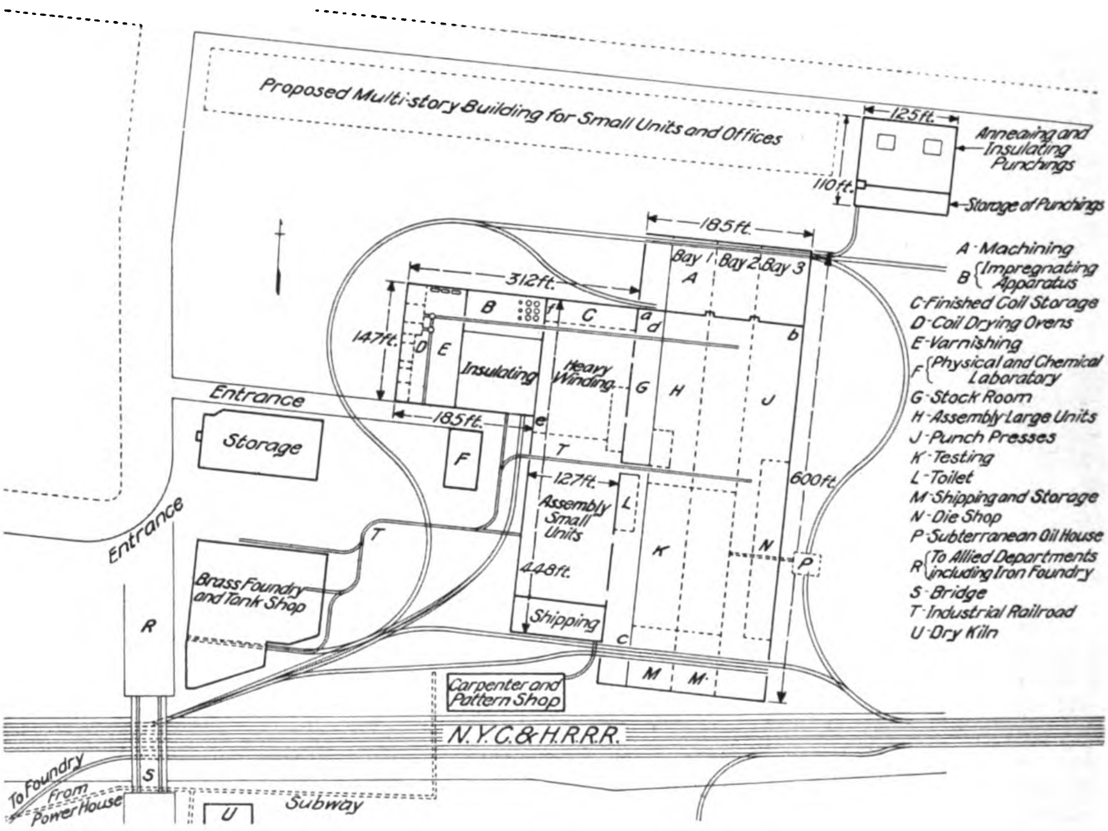


Fig. 2. Plan of Principal Buildings

The main building abuts at its northernmost end upon rising ground, and the floor of that portion behind the line a-b is accordingly at a level intermediate between that of the main floor and the gallery over c-d. On this raised portion is located the receiving room for material to be used in the building, brought directly by cars shipped over the N. Y. C. R. R., on a spur track provided for the purpose. The general machine shop of the department (partially shown in Fig. 4) is also here located. Here are the shears for cutting up the large sheets of steel into strips of suitable widths to go to the presses nearby on the level below. There are also installed the large and small planes, drill presses, milling machines, lathes, grinders and miscellaneous machine tools necessary to perform the various operations required to prepare for service the largest water-cooled transformer tank, or the comparatively small and delicate regulator armature, with its fine exactness. Below the machine shop in Bay 3 is the punch press shop, equipped with the best modern presses with individual motor drive and fitted with the latest pattern of shearing dies, which allow them to operate at maximum efficiency. Immediately connected to the punch press shop is an extensive die shop, for the proper up-keep of dies and machines demanded by high grade work essential to a good transformer.

Fig. 3. Main Building; 600 ft. Long, 185 ft. Wide

The main bays, 1 and 2, opposite the press shop in Bay 3, are devoted to the assembly of the medium and large transformers. This is partially shown in Fig. 5. In Bay 2 are located the long concrete pits in which, to facilitate accessibility, the large air-blast and water-cooled transformers are placed during assembly. The portion of Bay 1 under the gallery is devoted to a generous stock room, connecting through a fire wall with a smaller one; the combined rooms containing all materials for the winding and assembly departments, to which they are adjacent. Next to the assembly is the Testing Department. Here no necessary expense has been spared to make the department complete in every respect. The extensive capacity is so completely subdivided into a variety of especially designed units, elaborately interconnected, that the many classes of apparatus, of all voltages, frequencies, and currents, can be completely tested under their proper conditions.

Power received from the power house at 2300 volts, two-phase, is converted through suitable motor generator sets, to be received on the D.C. distributing boards. Thence it is supplied to D.C. motors, which, in turn, are direct coupled to special generators delivering their output to the A.C. distributing boards, shown in Fig. 6. From these, by means of the flexible control of the auxiliary D.C. equipment, power of any desired voltage and frequency can be obtained. In construction these boards follow the latest practice in central station installation. They are, in the first place, strictly fireproof, consisting entirely of metal, concrete, slate and marble. All wiring is found either on the back of the switchboard panels or in suitable conduits beneath the floor.

Pilot lamps show the condition of excitation for every circuit. Machine frames, transformer cases, switch boxes and all low voltage transformer secondaries are grounded. The large transformers that are assembled in pits are likewise tested in this position with the same intention of rendering them accessible at all points. These pits are arranged immediately behind the board, in such a manner that temporary wiring, and the resultant danger to operator and apparatus, is minimized. Further protection is afforded in that these transformers, during test, are enclosed within a wire fence, the gate of which cannot be opened without breaking the field circuit of the alternator supplying the power.

This testing plant is placed entirely in the care of experienced permanent operators, whose duty is to operate it intelligently and carefully, supplying conditions demanded by the testing force in charge of the transformers. Not relying entirely upon these skilled operators, however, the design, so far as is possible, provides safety devices for protection, including interlocking mechanisms to guard against improper connections which might result in burning out machines, instruments or rheostats. From a subterranean oil house, indicated in Fig. 2, pipes are lead to the testing pits, and 5000 gallons of the special grade of oil used in transformer work can be supplied at any desired temperature from tanks equipped with heating devices. In the pits an outfit is installed for testing the water coils of large transformers to 1000 lb. pressure per square inch, to provide against a defect fatal to the safety of the transformer. It is so arranged that any possible leakage water would be immediately conducted to the Housatonic river, and apparatus is therefore insured against damage therefrom. There is also piped to these pits a supply of warm dry air, for finally drying the surfaces of the various parts of the large, high voltage transformers before filling with the protecting oil, as these surfaces become moistened by natural atmospheric condensation. At suitable points about the station, testing tables are to be found containing all the instruments necessary to make various electrical and hydraulic measurements involved.

Those who are familiar with the process of measuring the temperature rise of transformers under various conditions of load, know of the difficulties that arise when attempting to perform this delicate work on self-cooled apparatus that is located in a large volume of air subject to the rapid variations in temperature which occur during the 24 hours of the day, at the various seasons of the year. They will then appreciate the value of the special room provided for this class of work, the temperature of which may be controlled, and the disturbing influences of nature or of other apparatus eliminated. Here those measurements of refinement are made upon which are based the standards of design that make it possible to closely predict the performance under various conditions, of the many special classes of apparatus built.

The testing space is divided to correspond to the several lines of work to be performed, and is so located as to render most direct the

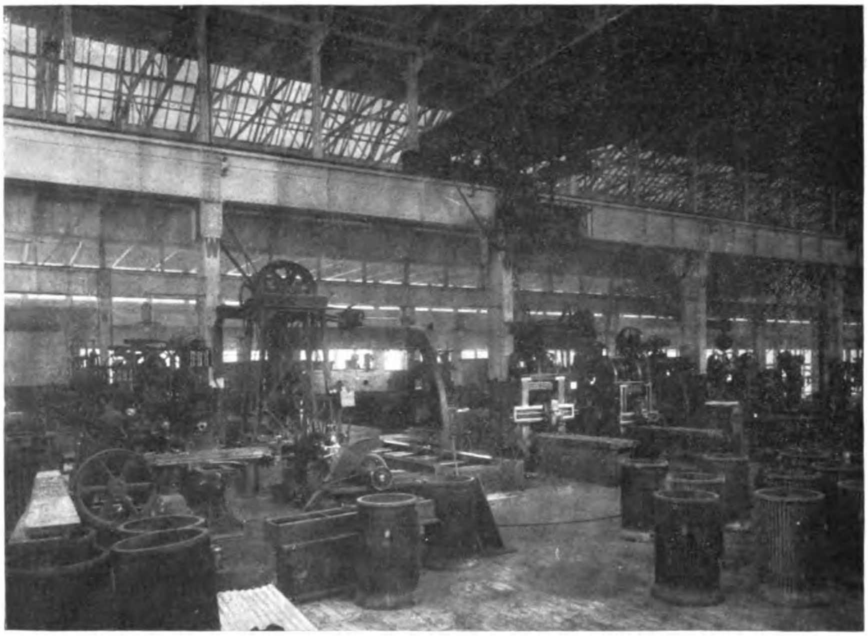


Fig. 4. Section of Machine Shop

route of work from assembly to shipment. Standards requiring a prescribed rigorous test are sent to one portion of the department, where by special arrangements made exclusively for them, they are tested with the greatest of care and promptness. Apparatus built in considerable quantities, yet not classed as standard, is tested in a second space; and finally, the work classed as special has yet another place provided. Each distinct class of apparatus is thus cared for in a manner which by subdivision permits of that specialization in both man and equipment, productive of maximum efficiency.

Beyond the testing, lies the Shipping Department, from which transformers are sent forward to customers, being loaded upon the car while protected by the same roof under which they are manufactured.

The gallery over c-d in Bay 1 contains the winding department for the small work, divided at the middle by the insertion of its stock room and local office. Fig. 7 is a view taken from the stock room, showing the northern half.

In the saw-tooth building, favored by the excellent northern light afforded by this construction, are located the assembly of the small work, the winding of the large, and the insulating of both. A very good idea of the small assembly may be obtained from Fig. 8, which shows that portion devoted to the small standard Type H lighting transformers. The portion of the building to the left of e-f, Fig. 2, is given up entirely to the various processes of insulation, for which isolation from the remainder of the work insures cleanliness, so essential to satisfactory work. One room, as indicated, is occupied by the new impregnating apparatus, which is installed in groups of three units and equipped with all of the necessary accessories.

Beyond this lies the room containing the drying ovens, a general view of which is shown in Fig. 9, while adjacent thereto is a room for preparing coils for impregnation and for making miscellaneous insulations. The construction of the ovens is not unlike that of a cabinet containing bottomless drawers vertically disposed. The large, well ventilated chambers are sub-divided into a number of narrow sections, closed by the front of the slides. To open, the motor is started, and any desired section is drawn out until at the extremity of its travel, the rear of the slide closing the oven. In this open position the oven is charged with the coils to be baked, after which it is closed as before. It then receives a continuous supply of fresh, warm air, at a temperature under control, the air charged with the moisture and volatile products driven off from the coils being exhausted outside of the building and replaced by fresh air from the intake of the heaters, which, in turn, is forced evenly throughout the entire oven. When coils are sufficiently baked the oven is opened and left in that position a short time before unloading, being cooled by a blast of cold dry air forced through a grate in the floor underneath. By the special construction of the ovens, which prevents the escape of heat or the entrance of cold air, the coils are kept under the uniform temperature.

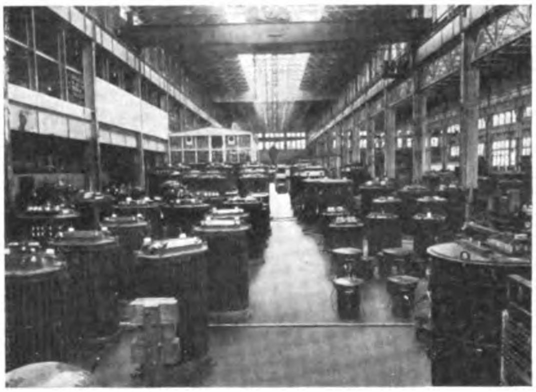


Fig. 5. Assembling Department for Medium and Large Size Transformers

The new foundry (shown in Fig. 1) is worthy of special consideration. It embodies the very latest ideas of continuous pouring foundry practice, and has a capacity sufficient to care for the entire production of the department. The cupolas, tops of which are just discernible above the roof, are located in the shorter branch of the L-shaped building, the main branch of which is constructed of two stories. The lower floor is used for the assorting, mixing and general preparation of the moulding sand, which is carried to the floor above by means of conveyors, where it is moulded by the aid of the latest forms of moulding machines. Cupolas are fed by means of an elevator, which meets the spur track from the railroad on the lower extremity, and cross tracks on the upper floors. Molten metal drawn from the cupola is conveyed to the main floor, where it is poured into the moulds, which, upon cooling, are broken up on heavy grids that retain the castings and allow the sand to return to the floor below for further use. Castings thus left unencumbered upon the main floor are carried along the length of the building to the machines which are there installed for chipping, snagging, etc., to be in turn carried below for inspection and test by hydraulic pressure. In all of these operations, manipulation is aided by the use of the latest hoisting and conveying machinery, with which the entire foundry is supplied. By this equipment, it is designed to pour continuously in a manner not possible in the ordinary foundry, which operates intermittently to allow for the making of moulds.

The demand for several varieties of insulating compounds which can be readily moulded for use into any desired form, has necessitated the erection of a new building devoted entirely to their manufacture. Here are found grinding, sifting, mixing and moulding machines supplied with steam and hydraulic pressures, and the necessary machine tools for making the moulds and repairing the apparatus.

The building in which are grouped the brass foundry, forge and tank shops, needs no further description than a statement to the effect that it is in every way equipped to perform the usual functions of such shops, and the department is in this, as in other respects, self-contained, in that the wants from the smallest forging or brass casting to the largest water-cooled transformer tank of boiler iron construction can be internally supplied.

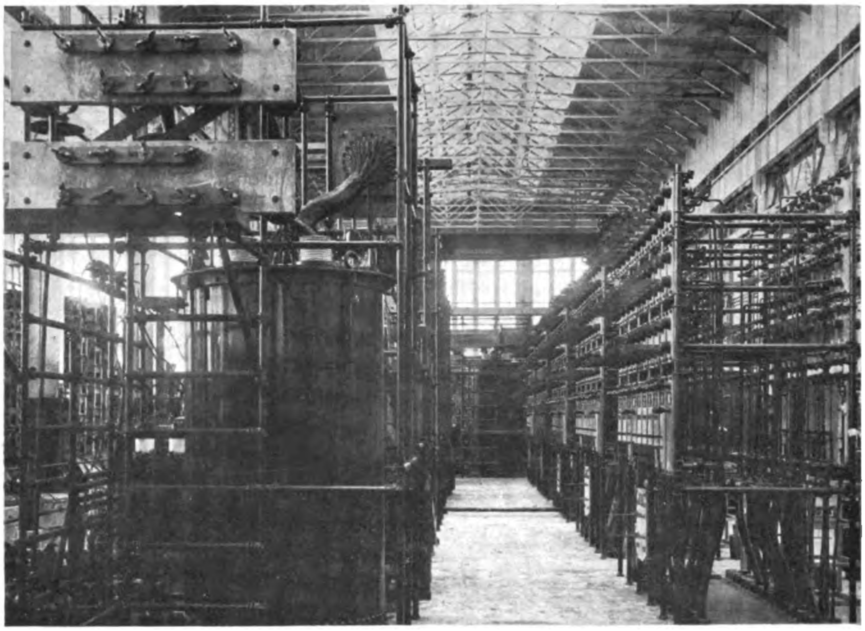


Fig. 6. A. C. Distributing Switchboards, Testing Department

The building shown in Fig. 10 is designed especially to care for the handling of punchings from the Punch Press Department. This building is so constructed on sloping ground that, while its major portion is one large ground floor, there is in addition a floor of much smaller area at a lower level, offering in this manner common facilities both to the present buildings and the proposed ones.

The punchings from the Punch Press Department, arriving by industrial railway at the door of the lower portion shown in the figure, are conveyed by elevator to the floor above where are located the latest type of oil annealing furnaces. Here they are transferred by crane to specially constructed charging devices which carry the heavily loaded annealing pots into the furnaces. A generous distribution of pyrometers in connection with a very nicely arranged switchboard, enables the operator to ascertain with minute exactness the temperature of any portion of the furnace, or, in fact, any portion of a given pot within the furnace; while the many nozzles of the burner permit the complete control of these temperatures. When the punchings have been removed from the furnace, they are carried into an adjacent room, to be coated on one of the several enamelling machines. Leaving this machine, they are mechanically conveyed to the room below, where they are sorted, built into cores, pressed up, and stored ready for use.

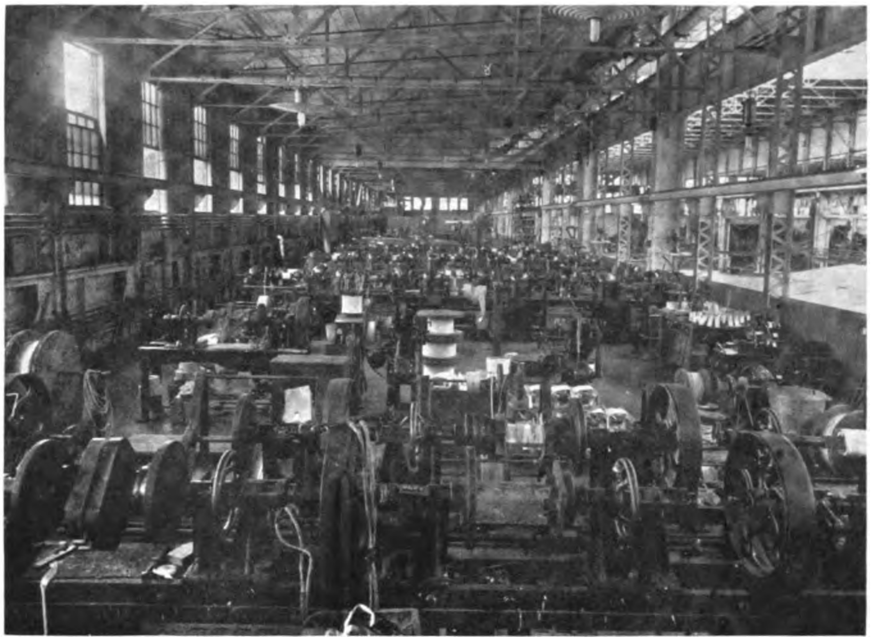


Fig. 7. Winding Room for Small Transformers

A plant has been installed in this building for drawing and rolling copper to any desired size, as well as for covering it. This is used for special work which does not conform to standards.

We come next to the pattern shop. This consists of three stories, the first of which is occupied by a carpenter shop, and the second by the pattern shop, both containing sufficient facilities to care for the wants of the entire plant. Above these on the third floor are the designing and drafting offices of the department, the regular building for which has not yet been erected. These are connected by bridge to the general offices in the office building, found immediately over the space marked "Shipping."

Co-operating with the wood-working shops is the new Dry Kiln, located, because of the fire risk resulting from its intimate associations with oil and resin impregnating processes, on the south side apart from the large buildings. This cement structure is divided on the ground floor into several compartments, temperatures of which are under control, while the upper floor serves as a heated storage room in which the wood is maintained thoroughly dry until subsequently filled with oil, japan or resin before use in the transformer.

An important accessory to the department proper is the Physical and Chemical Laboratory, centrally located in a three story brick building. The ground floor consists of the research laboratory, which is equipped with various electrical, physical and chemical apparatus, for investigating the characteristics of the materials and processes involved in the several lines of manufacture. The middle floor of the building contains the headquarters of the factory organization, while the top floor is devoted to a reference library and the standardizing laboratory, a division co-operating with that located on the ground floor.

The following is a summary of the processes through which materials pass after entering the plant. Raw material enters at three general points. Sheet steel, delivered to Bay 3 of the large building, is assorted, recorded, stripped into suitable widths, and delivered immediately below to the press department; from which it is sent in form of punchings to the annealing building, where, after operations described, it is stored, to be drawn upon the demand of the assembly department. Insulation, wire, and miscellaneous stocks, are delivered to the industrial tracks near the point E, Fig. 2, whence they are carried to the various stock rooms for which they are intended. Pig iron, moulding sand, etc., are carried by a third spur directly to the foundry, while a branch takes care of the materials used in the moulded insulation building.

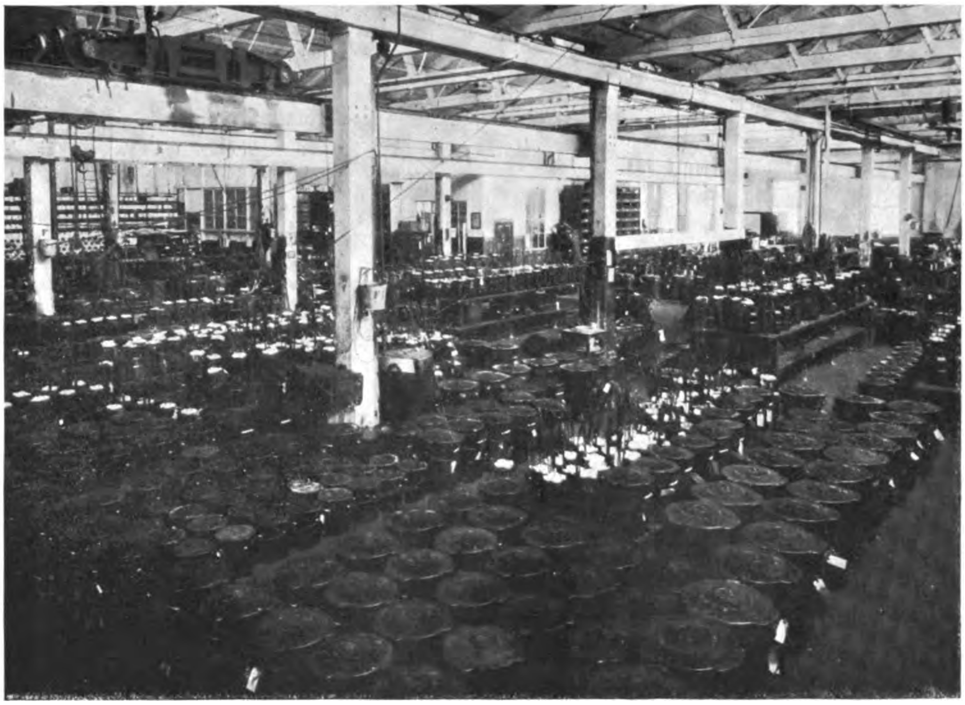


Fig. 8. Assembling Department for Small Type H Lighting Transformers

Castings sent forth from the foundry after inspection, are conveyed to the north side, where, if they happen to be bases for the large transformers, they stop at the tank shop to have their heavy sheet steel sides riveted on, and the entire operation of building the tank with its accessories performed. They then follow the miscellaneous castings to the machine shop, at the extremity of the large building, where the necessary machine work, such as planing, drilling, or tapping, is completed, when the tanks are ready to be conveyed by crane to the proper point on the assembly floor in the same building. The windings for small transformers, completed in the gallery, pass from the elevator to the industrial track below, where they join the windings of the large transformers, made in the space indicated for heavy winding. These windings then pass to the adjacent rooms, to be placed in ovens at proper temperatures and baked, prior to further drying in the vacuum chamber of the impregnating apparatus. This done, they are filled with the insulating compound, driven in under pressure till the most remote fibres of the insulation or interstices between turns are filled. If the coil is intended for high voltage work, it is then further treated by many successive layers of tapings, varnished and baked in ovens provided for that purpose. It is then placed in the finished coil storage to protect it from injury, moisture or dirt until it is desired by the assembler to meet the core, case and other parts of the transformer which have been in preparation. After these different parts are brought together in assembly, they pass through to the testing room, where they are very carefully tested to insure against any defect, and after this are turned over to the shipping department for packing and loading upon the cars.

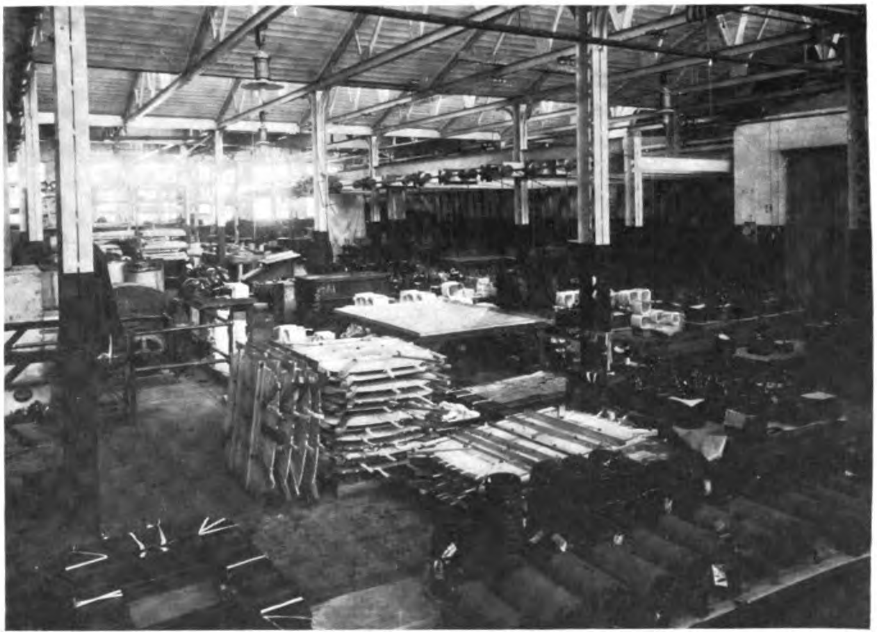


Fig. 9. Insulating Room and Drying Ovens

Thus the materials coming in from the various points converge radially toward the center for assembly, and thereafter follow the same course through to shipment.

The paths of the windings and punchings describe loops, which join with the general progress of the work in a straight line through the building, in such a manner that confusion from work doubling back upon itself is avoided. Near the center of activity is located the factory departmental headquarters, visible in Fig. 5, wherein are grouped those responsible for the various phases of the work. About them, in the midst of and in immediate contact with the several branches, are the respective foremen directly in charge.

A few figures showing the magnitude of this development may be of interest. The total area under one roof, comprising all facilities which can be advantageously so disposed, amounts to 237,000 square feet. The total area of the department is 400,000 square feet, a space greater than the combined areas previously devoted to transformer manufacture at Schenectady, Lynn and Pittsfield, and fifty per cent. more than the entire plant of the old Stanley Company, out of which it has developed. This is, however, not the final extent of progression, for preliminary plans have already been drawn for a five story building (indicated by the dotted rectangle in Fig. 2), to care for the increasing demand of a rapidly growing business. With the exception of the portion in the front end, which is intended for general offices and those of the department previously mentioned, it is planned to devote this new building to the manufacture of the small supply apparatus, such as the standard lighting transformers, regulators, mercury arc rectifier apparatus, and press work. This will then leave the main bays exclusively for the larger class of apparatus, for which, by reason of their height, they are particularly adapted.

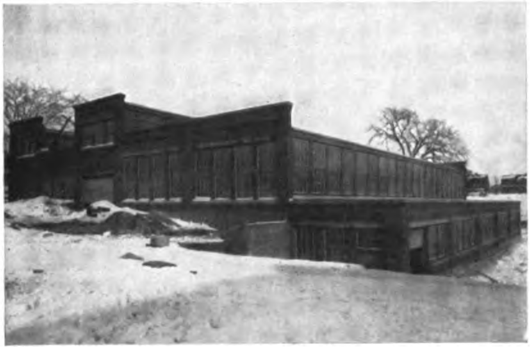


Fig. 10. Building for Annealing, Coating and Storing Punchings

It will be observed that there is a most unusual opportunity in Pittsfield; *viz.*, that of a large, well developed, isolated, and practically self-contained department, having the advantages of a small plant, yet backed by all of the reserve power of a large corporation.

WIRELESS TELEGRAPHY

By Prof. Elihu Thomson

Something over thirty years ago, Prof. E. J. Houston and the writer made some experiments, which in the light of our present knowledge, have acquired additional interest to that which they originally possessed as novel experiments at the time.

An induction coil, capable of giving sparks several inches long between its terminals, was operated on the lecture table of the Department of Physics, on the first floor of the Central High School of Philadelphia. One of its terminals was well grounded on the water piping, and the other connected by a wire about two feet long, to a large tin vessel of two or three square feet of surface, mounted on a glass jar as an insulator. Sparks passed between the terminals of the coil—the discharge of the capacity of the tin vessel to earth. It was found that when the coil was in operation, tiny sparks could be seen in the dark when the point of a lead pencil was brought as near as could be to, or to incipient contact with, metallic bodies; not only in the same room but all over the building, even to the top floor and observatory, about 90 feet above. Instruments, apparatus in glass cases, metallic vessels, doorknobs, etc., were tested and found to respond. Particularly noticeable were sparks from isolated stoves in some of the rooms. We at the time had no doubt that these disturbances could have been noted in adjoining buildings. Lightning discharges, as is well known, frequently produce local sparking between metal bodies near to each other.

The phenomenon was significant of the fact that a sudden relief of electric stress might be far reaching, if delicate apparatus for its detection were available.

In the present paper, an attempt will be made to trace the connection between wireless transmission and the ordinary low frequency alternating current transmission; so as to arrive at a consistent development of ideas whereby, in the wireless transmission system, there may be seen to be in operation principles which are much the same as with low frequency alternating arrangements of circuit; modified, however, by the different values of effects introduced in response to the use of high frequency oscillatory or sustained high frequency alternating currents. There is no intention to describe forms of apparatus used in transmission or in receiving, nor other details which are quite widely varied, and which have been fully described in various papers dealing with the subject. An attempt will simply be made to present a point of view in the endeavor to render clear to those who have not given special attention to the conditions of wireless transmission, the nature of the operations which are involved.

In the ordinary low frequency alternating current system, the energy is expended in a number of different ways; and, of course, the main object of the system is to convey energy from one point to another, as from a source of power in a station to translating devices or motors somewhere upon the line system. In carrying out this plan of transmission, however, there are certain losses of energy inevitably involved. Where the frequency is quite low, we are chiefly concerned with the ohmic drop in the circuit, or the absorption of energy which is converted into heat in consequence of the fact of our materials not being perfect in conductivity.

We have, besides the mere losses in ohmic resistance, magnetic hysteresis, and eddy currents, certain enhanced resistance loss which is due to the skin effect, or crowding of the current to the outside of the conductors; an effect, however, which is not appreciable in the ordinary low frequency circuits, but becomes important as the frequency rises. There is also the added loss due to the charging current of the line, which current does no work. The parts of the line simultaneously at different potentials act as charged conductors or condenser surfaces, and are charged and discharged at each alternation, superposing an idle or leading current on the line current. This effect, however, may be balanced more or less by inductance, either normally existing or purposely introduced; but where iron is used to secure this, added magnetic losses are involved.

Were the dielectrics between the conductors (the air and other insulating materials) perfect dielectrics which could be electrostatically stressed and released without involving loss of energy, the losses due to charging current could usually be neglected in low frequency work. In cables, where the conductors are close together, separated by comparatively thin layers of dielectric, the loss may be considerable, even at comparatively low frequencies, unless the dielectric has been chosen for low leakage and low dielectric hysteresis. The leakage of the line also adds a loss due to the flow of current from one side to the other over paths which are not intended to exist, but which cannot be avoided—as when the insulators are imperfect in insulation.

These effects, of course, are enhanced by increase of potential, as is also another source of loss, namely, surface ionization (or electrification to a certain distance from the surface of the conductor), which indicates its presence by a bluish light in the dark (called aureola or corona) and a hissing sound in air. Here the dielectric layer, or air layer around the conductor, is actually penetrated by incipient spark discharges, with the production of heat and loss of energy. Mershon has shown that even below the critical point, or point where this blue discharge begins, there is a leakage, or loss in air, increasing with the product of two influences; namely, the amount of water vapor present in a given volume, and the degree of humidity or saturation of the air, which in turn depends upon temperature.

Ordinarily only these losses just enumerated are noticeable with the common frequencies of alternating currents. Generally no account is taken of another slight loss of energy; namely, that due to radiation. The periodic changes of potential of the lines, especially when separated some distance, is accompanied by a wave of stress in the surrounding medium, the ether, which, however, spreads out to an unlimited extent, like the dropping of a stone in a pool of water producing waves which extend onward indefinitely.

Accompanying the periodic flow of current in the conductor, there is also, in the surrounding medium, a magnetic radiation originating at the conductor in the lines of force which surround it, spreading outwardly to illimitable space in magnetic waves. It may be said, then, that any conductor conveying a current, or subject to alterations of its electrical condition, produces in the ethereal medium of space, a radiation of energy in the form of electromagnetic waves. When, however, the conductors of a system are so enclosed or arranged that one surrounds the other, with a dielectric between, this radiation is neutralized; for the magnetic lines are then generated in the space between the conductors, and the dielectric stresses are also located in that space. If, however, the conductors stand alone, far away from any neighboring conductor, then the radiation or electromagnetic wave production goes on unhampered, or one may say, the radiation is free.

It has many times been pointed out that the actual conveyance of energy in an electric circuit is not in the wire, but in the medium or ether surrounding the wire, or in the ether or dielectric between the wires where the conductors are concentric. The radiation, therefore, would represent that small fraction of the energy which, during a pulse or half wave, starts outward with the velocity of light to stress the surrounding ether; and which continues outward, like the waves in the pool when the stone is dropped, spreading onward to an indefinite or infinite distance. It would avail nothing to attempt to stop the wave, to pull the stone back the moment it was dropped, for the wave having once started, does not return. In the same way, the electric pulse having started the electromagnetic disturbance, a portion of the energy expended continues on outwardly. If in the case of the stone in the water we give it a periodical raising and lowering, this sets up a continued system of waves spreading outward. So in the alternating current circuit the changes in the electric condition set up similar electromagnetic waves extending outwardly, only in this case they are represented by the electrostatic stresses in the ether, or electromagnetic lines around the conductor.

We have assumed in the foregoing that the frequency is low. Let us suppose that the ordinary frequency is raised one hundred times, so that instead of, say, 60 cycles we have 6000 cycles per second. It will now be found that the skin effect is so enhanced that it is desirable to spread the conductor out in sheets, or use multiple wires some distance apart, or make the conductor a hollow tube, taking out, as it were, the ineffective core and using the material to enlarge the diameter. We will find also, that the charging current, in relation to the line current, has greatly increased; in fact, in about direct proportion to the frequency; while the extension of the conductors into sheets or tubes still further increases the value of the charging current, or the condenser effect of the line. Naturally, if there is a dielectric loss, this also is increased in the same way. The ohmic drop, except for the skin effect, and the leakage drop (such losses as are dependent upon resistance purely) would be unaffected, except for the increased values of the current due to the increased charging current, etc.

As each wave will at any given potential produce a radiation effect depending on the gradient of stress, or rate of change, and not upon the periodicity, the radiation of energy will increase with the frequency or pitch of the waves. Hence, as the frequency rises, more and more of the energy under any given potential will be sent out into surrounding space. As stated before, the skin effect may be avoided by spreading out our conductors; the significance of this in wireless work will be shown later.

If we continue raising the frequency, we may reach a point at which a dynamo supplying given energy is sufficiently loaded with a very moderate length of circuit, due to the radiation losses and charging current; so that we no longer need to assume that the system is one for transmitting energy, in the ordinary sense, to translating devices connected across the circuit. The system becomes, as it were, merely an arrangement for the enhancement of the effects of the charging current and the radiation, with the practical abolition of the other conditions of working that are normal to a low frequency line. With a frequency of, say, 100,000 cycles to 500,000 cycles, our conductor must become a surface if we are to avoid the opposition or attenuation due to self-induction. A very moderate length of line suffices to absorb the load, and the system becomes, substantially, a radiating system.

In the Hertzian wave apparatus we have the extreme of this case. Here an induction coil simply feeds into a Hertzian oscillator; consisting of two polished balls separated somewhat by a small space, with wings sometimes extending outward from the balls. Such an arrangement may be said to be a sort of electrical tuning fork, or one in which the discharges occurring between the two parts, oscillate with a fairly definite period or rate, depending upon the electrical constants of the apparatus. As a rule, the shorter and the smaller the affair is, the higher the frequency, so that with small polished balls, frequencies in the hundred of millions per second may be obtained. The Hertzian apparatus was particularly well adapted to the radiation of energy quickly. The waves damped themselves rapidly. If the two wings of the apparatus had been brought nearly together, more or less parallel, the frequency with any given size would fall and the oscillations be more sustained. In this case, the energy stored would be radiated over a longer period. At the same time, the apparatus would be capable of storing more energy.

To come now to consideration of the conditions in wireless work, where one-half of the Hertzian wave apparatus is abolished, and where one terminal of the oscillating system is put to ground—originally through a spark gap, but later by direct connection through adjusting or air core induction coils—we will find we have substantially an alternating system in which one terminal is grounded; as if an alternating dynamo had one terminal grounded while the other terminal was connected to a wire or structure, which, while it led away, did not lead to a distant point completing the circuit through translating devices to ground, but merely terminated at some height in the air. Here the function of the charging or energy supplying system is merely to furnish that energy which, with other and comparatively minor losses, is expended in radiation from the antenna into space around it.

Such a system, as in the case of the Hertzian arrangement, may have a period or normal frequency; as when the antenna discharges through a spark gap to the ground, such a discharge of the charged upright wire taking place as a high frequency oscillatory current, while the energy of the discharge is to a large extent radiated in ether waves in all directions around the wire. While originally a spark gap was put between the lower end of the antenna and the ground, it is now usual to employ an air core coil and supply the energy by induction, and in receiving apparatus the same arrangement is put into use, for the system is reversible. Dynamos, as initially planned by Professor Fessenden, can be constructed of sufficiently high frequency to become the source of excitation of a well-tuned system.

To digress a moment, it may be even said with truth that a lightning discharge is akin to the discharge of the elevated antenna. Here the cloud contains an electric charge which frequently finds the earth by opening a path for itself downward, but it is to be doubted whether, in such case, it is anything in the nature of a real oscillatory current. According to a definite law enunciated by Kelvin, it is an essential, in order that the discharge shall be oscillatory, that the system shall not contain too much resistance, or any oscillations would be damped out at their inception. That there is large resistance in lightning stroke is seemingly evidenced alone by the heating effect throughout the whole length of the spark discharge.

At any rate, if oscillations do occur, it does not seem possible that they should be rapid. The breakdown of the dielectric between cloud and earth is, of course, extremely sudden; the pulse front is steep, and it may give rise to high frequency oscillations in metallic systems beneath, such as electric circuits, the frequency of such oscillations depending more on the constants of the circuit oscillating, or upon the portions of the circuit affected, than upon the induced effects of the lightning itself; just as a bell may be struck by a mallet a sharp blow, but the mallet does not vibrate as the bell does, the bell taking on its own rate.

Suppose we have a body insulated, say a vertical wire, and a charge therein which may be assumed positive. Then electrostatic stresses, sometimes called tubes of force, extend all round to the earth's surface, which becomes in the vicinity negative. If the positive charge now runs down to earth through a spark gap, the stress lines are immediately changed in relation, and an electric current flows, producing magnetic disturbances in the ether around the wire in the form of magnetic whirls or surrounding lines. If the circuit be capable of oscillating, that is, if the discharge gap be proper and there be no great resistance, the positive charge in passing to earth, owing to self-induction, overruns; and the negative going up, in like manner overruns; so that the next instant the vertical wire is negative while the ground below is positive. This overrunning or oscillation takes place in progressively decreasing amplitude, until the energy stored in the original charge has been dissipated; partly in the spark gap, partly in resistance, partly in dielectric hysteresis, and partly in the radiation of electromagnetic disturbances or waves of definite frequency around the antenna.

These disturbances spread out in circles around the axis of emanation, or the center of the antenna; but current also runs out at the foot of the antenna to join and neutralize the charges of the earth's surface near thereto. In each case of the current moving outward from the foot of the antenna, there is a feeble current extending therefrom, which in ordinary cases follows the upper part only of the moist earth layer below; or better yet, if the apparatus is directly connected with the sea, follows the surface of the salt water, spreads out as an oscillatory current in the surface so far as the magnetic whirls around the antenna extend, and so far as the electrostatic stress lines arising from each alternating charge extend. To put it differently, the surface of the sea is the conductor in the system, more important than the antenna itself in directing the spread of the electromagnetic disturbance or radiation of energy. The surface of the ground or sea then performs the function of the conducting wire in an ordinary alternating system. It is, however, an indefinitely extended sheet, and may be curved as is the surface of the earth. The electromagnetic waves cast off in consequence of the increased density of stress or lateral pressure in the antenna wire as compared with that of the surrounding earth have, so to speak, their feet in the water.

If one could picture the effect, assuming a wireless station in midocean on a ship, the surface of the ocean would be traversed by a high frequency current, consisting of charged areas, generally circular, of alternating positive and negative character, with neutral or zero zones between; and the spacing of these would depend upon the frequency of the emission. Above these areas would be an extended system of stress lines or tubes of force, projecting from one electrified zone to the other, the zones widening and speeding onward and outward with the velocity of light. Over the centers of the electrified zones as a maximum would be a system of magnetic whirls, parallel to the surface of the sea, consisting of nearly circular magnetic lines ever expanding and passing outward, while guided by the current in the sea itself; just as the current in an ordinary alternating circuit guides the energy which is flowing in the ether outside thereof.

In the early days of the wireless transmission work, there was considerable discussion and mystery as to the reason why the waves seemed to follow the curvature of the earth, instead of spreading out in straight lines from the axis of the antenna; just as it was at first thought by many that the spark gap was the locus of the radiation. If we bear in mind, however, that as the function of the disk-like conductor, the sea or surface of the earth, is that of a guiding and directing circuit, it is easily understood why the curvature of the earth furnishes no barrier to wireless transmission.

In such a system of radiation of electric energy, practically all the energy of the circuit exists in the electrostatic and magnetic waves spreading outwardly; but as this spreading occurs in all directions, assuming that the conductivity of the surface below is uniform in all directions, it is manifest that at any one point at which the signals are to be received, an almost infinitesimal part of the energy sent out can be caught. The greater the distance away, the less this fraction will be; but here comes into operation the principle which enables us to enhance the effects of the transmission. If the frequencies of sending and receiving be controlled, or the receiving antenna, which extends upward into the region through which electrostatic and electromagnetic waves pass, is arranged so that its natural period of electric vibration or oscillation is the same as that of the transmitter apparatus, then interference is checked, or in the latter case, each minute impulse is added in its effect to that of the one preceding, and a definite amount of energy is so obtained suitable for the working of the delicate receiving instruments. The manner of the delivery of such energy to the receiving antenna may be briefly referred to.

The traveling electrostatic waves, together with the magnetic whirls, spreading outward from the sending antenna, reach the receiving antenna; and since they represent disturbances of electrostatic conditions or stress, and also since they represent extending magnetic lines which cut the upright antenna, there is generated an electromotive force in the receiving antenna which tends to make its upper extension differ in electric potential, or become oppositely electrified from the lower end or earth below, following the waves which move at enormous velocity or the speed of light. By tuning or syntony of sending and receiving apparatus, the first slight disturbance may be added to, so as to affect the delicate receiver, which is either placed directly in the circuit between the antenna and earth, or is inductively related thereto through an air core transformer.

It is not to be understood that for mere conveyance of signals, tuning or syntony is an essential, but it depends somewhat on the principle of action of the receiver. But if non-interference of stations is to be secured, then some form of adjustment of such stations to different rates of oscillation or selection of frequencies, will become a necessity. Inasmuch, however, as the frequency is necessarily high, and may be hundreds of thousands per second, a minute fraction of a second only is needed for a considerable number of impulses to produce accumulative effects in the resonant or attuned antenna; so that rapid transmission, or many signals per second, can be secured.

It has been found as a matter of experience, that, particularly during sunshine in the daytime, wireless transmission with the usual frequencies of 500,000 or 600,000, has been often impracticable, or very feeble as compared with transmission during the night. It would seem that the sunshine, perhaps through the ultra-violet rays, produces an electric ionization of the air, and converts it into what might be called an electrically muddy medium; the ionized gases and particles in the atmosphere disturbing the clarity of the ether as a transmitting medium, by opposing the uniform and direct progress of the radiation of electromagnetic waves. It becomes an absorbing medium so to speak, receiving and probably converting the energy in its progress into heat. This is somewhat exemplified by the known absorption of the higher frequency waves of light by fog, while the lower waves, such as red light, penetrate fog much more freely. Professor Fessenden has shown, however, that if the frequency be lowered to the rate of from 70,000 to 100,000, then, although the response at nighttime may be much more feeble, the response in daytime is retained at a workable value. He has therefore introduced into wireless systems, under collaboration with engineers of the General Electric Company, high frequency dynamos; remarkable machines capable of developing the considerable output of one to three kw., at frequencies of 75,000 to 100,000 cycles. Such machines can, of course, through suitable air core transformers, be made to impress upon the antenna the desired potentials; and may, as pointed out by Professor Fessenden, be made with large outputs. Naturally the intensity of the electrostatic stress in the ether surrounding the antenna would depend upon the amplitude of the waves, or the maximum potential difference reached; while the magnetic effects which are produced around the antenna, due to the oscillation of the charges or the currents, will depend upon the maximum currents which are present in the vertical antenna.

It will be seen that, theoretically, if the surface of the earth were of uniform nature or conductivity, there should be a culmination of effect at the direct antipodes of the transmission station. It is probable, however, that the damping effect, or energy-absorbing effect, of the land surface in relation to the sea, is so great as to prevent any such result. It may, however, be possible that, as in the case of all such waves spreading out, there be places where there is a certain enhancement due to the culmination of impulses coming in different directions from the transmitting station, as around land areas. Such culmination may be, however, of too low value to be easily noted, and would naturally, if it exists at all, differ with different frequencies of transmission.

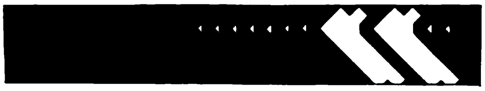
In the above, an attempt has been made to present if possible, a mental picture of the actions which occur in wireless transmission, with a comparison of the electrical effects with those normally present in other alternating circuits.

Manifestly, since the guiding transmission conductor is the water surface, or moist land surface, on account of the conductivity, it will be difficult if not impossible to effect a wireless transmission across a barrier of dry rock, such as a mountain chain without much moisture. Even a range of hills broken by rocky outcrops or dry soil beds, may constitute such a barrier. Transmission, however, might occur from one point to another on each side of such a barrier, if both stations were near a body of salt water which connected around the barrier; for the signals though enfeebled by the roundabout course, as tending to follow and be guided by the conducting surface, might still be of force sufficient to affect the almost inexpressibly delicate receiving devices which have been invented by the able workers in the field. Moreover, as pointed out by Prof. Fessenden, the electrical shadows of obstacles would be far less sharp with low than with high frequencies, a fact which may be of importance when obstacles of the nature mentioned above are encountered.

TRANSFORMER STEEL

By W. S. Moody

Iron being the only material in nature that is markedly magnetic, the first attempts to get the best possible magnetic material were naturally directed toward securing the purest iron. Consequently, we find that all early specifications of electrical manufacturers who desired the best grade of iron, stipulate "best Norway iron," this being the purest commercial iron obtainable. As Norway iron is notably very soft, it was also natural that softness should be considered essential.



Punchings for Core of Small Transformer, as Obtained from Sheet

In the very early history of the manufacture of generators, transformers, etc., core loss received no more attention than was necessary to limit eddy currents and prevent overheating in the material. This was accomplished by splitting the core iron in various ways; by the use of iron wire sometimes bare, sometimes cotton covered; by the use of iron strips, or by using laminated sheets with paper for insulation.

Charging Floor of Open Hearth Furnaces

Nearly twenty years ago the engineers of the Thomson-Houston Company, a predecessor of the General Electric Company, made the discovery that certain impurities in iron greatly improved its electrical characteristics, and that these impurities existed in much more nearly the desired amounts in commercial open hearth steel than in pure Norway iron.

There are four essential qualities for iron or steel which is to be subjected to magnetization by alternating current. These are:

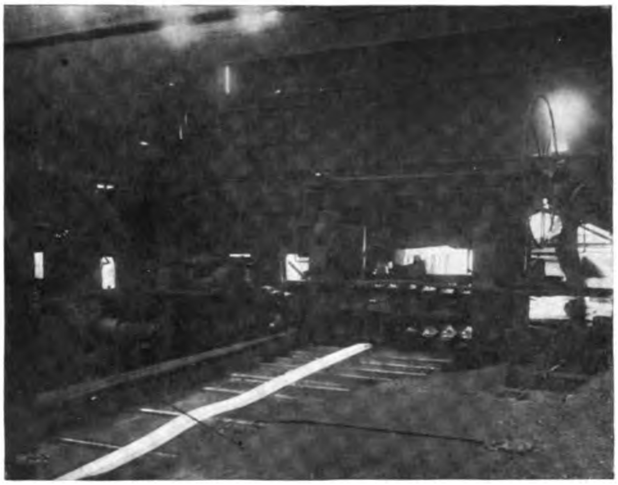
First. High permeability;

Second. Low hysteresis;

Third. High specific resistance (to limit eddy currents).

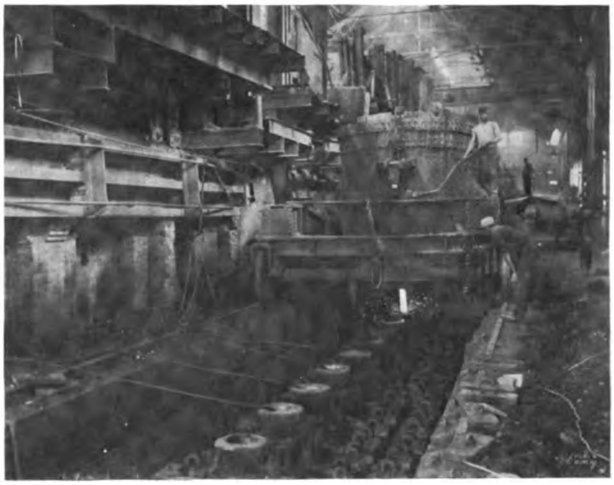
Fourth. Permanence with reference to hysteresis.

Steel is one of the most complex substances physically and chemically of which we have knowledge. The principal materials which appear as impurities are carbon, sulphur, manganese, silicon, and phosphorous. These elements exist in quantities varying from a few hundredths to two-tenths of one per cent. The proportion in which these materials exist in steel affects both the mechanical and magnetic characteristics, and some elements affect one more than the other. It is not strange, therefore, that experimenting for the best possible steel in all four characteristics has been of necessity largely a "cut and try" process, and that real improvement has been obtainable only after the expenditure of much time and money.



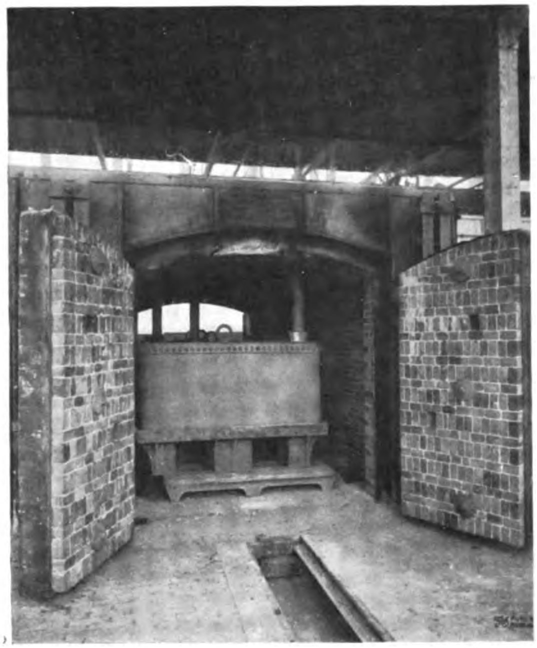
Rolling a 2000 lb. Ingot of Silicon Steel

The improved steel adopted by the Thomson-Houston Company was an advance over the various grades of iron previously used along all four essential lines mentioned above, but particularly in permanence. While the best Norway iron, carefully annealed, had initial losses little if any in excess of the grades of steel adopted, this condition was not maintained, and in the course of time even the moderate temperatures to which the material was subjected in ordinary operation resulted in greatly increased losses. The open-hearth steel, on the other hand, not only responded to the annealing, but the low losses obtained thereby were almost entirely permanent.



Pouring Ingots of Silicon Steel from 60 Ton Ladle

The improvement of open-hearth steel over Norway iron can be considered fully 100 per cent., that is, the steel was practically twice as good taking everything into consideration. It was found that the commercial open-hearth steel first used could be further improved for magnetic purposes by very careful attention to composition of material, and also the temperatures and length of time to which it was submitted in annealing. For many years slight but constant improvements were made by the General Electric Company with its electrical sheets, and a great amount of time and money was expended in investigations and in determining the best results.



Furnace for Annealing Punchings

Several years ago Dr. John F. Kelley, then with the Stanley Electric Mfg. Co., found that steel having a small amount of silicon showed some improvement over ordinary open-hearth steel, and a patent covering this was issued to him. At that time, however, the difficulty of obtaining this material at the mills prevented its use.

About this time the General Electric Company investigated the beneficial effects of using silicon in proportions 10 to 30 times greater than the amount of the impurities previously existing in good steel, and succeeded in overcoming the very serious problems involved in the making and rolling of such steel. These investigations thus resulted in the greatest recent advance in the manufacture of magnetic steel. This silicon steel, to an even greater extent than mild steel, disproves the theory that pure soft iron is the best possible magnetic material; first, because it is so very far from pure iron that the silicon should be classed as an alloy rather than an impurity; and second, because even with the most thorough annealing it is never soft. Sheet steel having silicon in such proportions, and properly produced in the mill not only gives far lower hysteresis loss than ever obtained before but also causes a very large reduction of the eddy current loss due to the fact that the alloy increases the specific resistance three to five times. In addition it establishes the magnetic stability of the steel so that the material is practically non-aging, even when subjected to imperfect conditions in manufacture or excessive temperatures in use to an extent never approximated with other materials.

Realizing the great value of the alloy, both to the manufacturer and the user of electrical apparatus, the General Electric Company, notwithstanding its greatly increased cost, put the material into use in all its transformers, so that at the present time there are approximately 250,000 of these transformers in service. The laboratory tests of the permanence of the material have been confirmed by tests on many of the transformers which have had considerable service.

Parts of Small Type H Transformer

ELECTRIC THEORY OF MATTER*

BY PROF. HARRY C. JONES

JOHNS HOPKINS UNIVERSITY

The work which we shall discuss has primarily to do with the question of the power of a gas to carry an electric current, that is, the conductivity of gases. Gases under ordinary conditions have very little conductivity, but this can be increased in a number of ways; *viz*, by heating, by exposing them to ultra-violet light, X-rays, etc. But the one to which I wish to call attention is the high vacuum tube, which is a tube filled with a dilute gas. We apply the term "dilute" to gases as we do to solutions. A dilute gas contains a small amount of gas in a given volume. The vacuum tubes are good conductors.

For a number of years the work of the Cavendish Laboratory in general, and of J. J. Thomson in particular, has had to do largely with the question of the conductivity of gases. When an electric discharge is passed through a high vacuum tube, in which the gas is dilute, the so-called cathode rays are noticed; the fluorescent or phosphorescent light which is seen is due to the cathode rays.

What is a cathode ray? There was an international war waged over this question between Germany and England; the Germans said that the cathode rays were nothing but ether vibrations, while the English said this was not true—Sir William Crookes taking the view that these cathode rays were charged particles. Each faction went to work to prove its hypothesis. The Germans performed an experiment by putting a sheet of metal over the end of the glass vacuum tube, and showed that the rays passed through the metal. "We have you!" they said, "Can you imagine fine particles passing through metal?" It was difficult, in the light of what they knew at that time, to think of the atoms of anything shooting through a sheet of metal over the end of a vacuum tube. On the other hand, Crookes performed experiments which showed that these cathode rays are not vibrations of the ether. He interposed in the path of the rays a sort of paddle wheel, which, by the action of the rays on the vanes, was made to move along the glass tracks in the tube. Crookes won the victory. His experiments convinced the scientific world that these rays are not vibrations of the ether, but are material particles.

Thomson wanted to find out something about these particles. What is the mass of these cathode particles? What charge do these particles carry? If we can determine the mass and charge, we take a step forward.

For the determination of the actual values of e and m we have one of the most brilliant series of experiments, extending over a number of years, that has ever been carried out in any branch of physical science; and it is to these experiments that I wish to call your attention briefly.

A long cylindrical vacuum tube is filled with dilute gas. At one end we place the cathode; beyond this a perforated anode; and beyond this again a perforated metal plug which is connected to earth. The cathode rays passing through the perforations, strike the wall of the tube at the farthest end, forming a small phosphorescent spot of light. Now if we impress a magnetic field, the beam of light will be bent and will strike the glass at a point different from that struck when there was no magnetic field. Measuring the strength of the field and the deflection, we have the data for calculating the ratio of e to vm.

We now wish to determine the value of v, in order to get the ratio $\frac{e}{m}$. We insert into the tube two plates of metal, so arranged that the beam passes between them. Upon charging the plates the beam is now deflected in the reverse direction to that taken when the magnetic field was impressed. By suitably charging the metal plates, the electrostatic and the magnetic fields just equalize each other's effect, hence the beam occupies its original position. We can thus determine the value of $\underline{v}$, and as we already know the ratio of e to vm, we get the value of $\frac{e}{m}$. Assuming that this is clear, and that we know how to determine the ratio of the charge to the mass of the cathode particle, we take the second step, which is more difficult, involving a still more brilliant series of experiments.

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*Address before the Schenectady Section, A.I.E.E.

I wish first to call attention to one fundamental fact. It makes no difference what the nature of the gas is, whether air, carbon dioxide, hydrogen or what not; you always get the same ratio $\frac{e}{m}$. *This is constant for all gases.* Also the value $\frac{e}{m}$ is the same, no matter what the metal of which the cathode may be made.

How much charge does a cathode particle carry with it? If we knew the number of particles in a cathode discharge tube, and could measure the conductivity of the gas, we should know the charge carried by one particle. We cannot see the particles; they are moving with velocities, about one-tenth the velocity of light. There is, however, a method of determining the actual number of particles under conditions similar to those in a cathode discharge tube, and men far more capable than I of judging, have said that they regard this as one of the most brilliant pieces of experimental work thus far done.

We have considered the method of determining the ratio $\frac{e}{m}$. If we can determine e, the charge carried by one ion, we will know m, its mass. Thomson carried out an experiment based on the assumption that both positive and negative gaseous ions act as nuclei for the condensation of water vapor. Water vapor in the atmosphere condenses around charged particles. Suppose we pass X-rays through a balloon flask containing water vapor and a gas which is free from dust. The gas is expanded, and condensation of the water vapor takes place in the flask in the form of a fine mist or fog; and it was shown that around every ion in the gas is condensed a globule of water; so that the number of globules of water that are formed is equal to the number of ions in the flask. Now all we have to do is to count the water globules! If you were ever present in a thick fog—say the London variety—you can imagine what it would be to try and count the water particles. They are very close together and moving rapidly. How are we going to determine the number of water particles in the gas?

Suppose we knew the total amount of water precipitated in the flask and knew the size of one drop; it is obvious that we could find out the number of drops. By allowing the mist to fall to the bottom, we can determine the total amount of water in the flask. The size of the droplets can be determined by the rate at which they fall—large ones, of course, settling much faster than small ones. By observing the rate at which the cloud settles, we have at once the value of v or the velocity at which the cloud settles; and knowing v we find, from Stokes's equation, the radius of the drop, r, and so find the volume. Therefore, if we know the amount of water deposited from the gas, and know the volume of one drop, we have all the data necessary for finding the number of ions in the same volume of gas, as it is equal to the number of drops.

And now to determine the charge carried by an ion: We know the number of ions present in the gas; we now pass an electric current through it and determine its conductivity; in other words, we measure the amount of electric current carried by the ions in the gas. Knowing the number of ions in the gas and the amount of electricity which they carry, we thus find the charge carried by one.

If we know the value of the charge carried by the cathode particle and know the ratio $\frac{e}{m}$ of the charge to the mass, we know the value of the mass. This is approximately one-thousandth the value of the mass of the hydrogen ion. More accurate determinations give about one to eight hundred. Thus we know what the cathode particle is. It is a *corpuscle*, having a mass one-eight-hundredth that of a hydrogen ion; and it carries a negative charge of electricity.

We get the same corpuscle from every kind of gas, whether hydrogen, oxygen, or carbon dioxide, etc. A common constituent can thus be split off from all gases. All elementary substances can be converted into gas; therefore, all elementary substances contain one common constituent, the corpuscle; and the old chemical definition of the atom must go, as many others have gone in the last fifteen or twenty years. It is shown that instead of these elementary forms of matter being entirely different from each other, they have one common constituent. What are its properties and what its mass?

The corpuscle, in terms of Thomson's work, contains matter and energy. How do we know that there is any matter in a corpuscle? The only way we can learn is by studying its properties. It has mass and inertia. These are the two fundamental properties of matter—do not confuse *mass* with ***weight;*** there is no greater blunder than thinking of weight as being a fundamental property of matter. Matter changes its weight, depending upon position—its mass remains constant. The corpuscle has both mass and inertia. That looks very clear. Thomson, however, was not sure that the mass and inertia of a corpuscle comes from any matter present. It had been shown mathematically that rapidly-moving electrical charges may have inertia. What part of the mass and inertia of the corpuscle is due to electricity and what to matter? Fortunately, nature has furnished us with a substance called radium, which shoots off beta radiations at different velocities. The more rapidly moving particles have more mass and more inertia than more slowly moving ones, and the mass and inertia of each have been measured. On the assumption that all the mass and all the inertia of corpuscles is due to the electric charge, Thomson was able to calculate how much greater should be the mass and inertia of rapidly-moving particles than of slower ones. Thomson based his calculation on the assumption that all the mass and all the inertia of the corpuscle were due to its electrical charge. There is nothing more stupid than to place figures on the board, but I must use a few to show you how the value of the mass is calculated and give a few results.

As the velocity of a charged particle becomes greater, the value of $\frac{e}{m}$ decreases. The charge remains constant, so it becomes evident that with the increase in velocity, there is an increase in mass. The calculated values agree with the experimental, which fact shows that there is absolutely no reason for supposing that the corpuscle contains *any matter at all*. All its properties, its mass and inertia, can be accounted for by the electrical charge which it carries. There is no reason to suppose that there is *anything present in a corpuscle but the electrical charge*.

Assuming that the electron or corpuscle contains no matter; that the mass and inertia are accounted for by the electric charge, the question arises—whence the conception of matter? This question was raised in a paper published some time ago by Ostwald. Some of the points brought up in the paper are rather metaphysical, but one fundamental thing is pointed out. We are accustomed to think of matter as the thing we know and energy as an hypothesis. Instead of knowing matter and hypothesizing energy, all matter is pure hypothesis. To think of carrying water, we think of the bucket in which the water is contained. Matter is the imaginary bucket which contains energy, and is created purely and simply out of our imagination, without the slightest bit of evidence for its existence. It has been created out of our imagination as a carrier for the energy which we know is present. It is rather interesting to know that the statements made in that paper by Ostwald have been for the most part verified experimentally by Thomson.

What is the unit of all matter? There is no matter at all in so-called matter. The ultimate unit of matter is the negative charge. One of the first questions then is, where is the positive charge? One of the first things we learn in connection with electricity is that where there is a negative charge there is also a positive one. In the early work of Thomson he had not found the positive charge. He said he did not know about the positive charge, and this has been the weak point. Where is the positive charge, and what is it doing?

If you take a hydrogen atom and split off the electron, what remains will be positively charged. It is interesting to see how easy it is to reason a thing out, and then go into the laboratory and prove that our conclusion is all wrong. The work I am about to describe was carried on by Lilienfeld, and the experiment was this: Suppose we take a glass tube, properly insert electrodes, an anode and a cathode, and impress not only a high e.m.f., but a heavy current. What will happen? The cathode particles we have been studying pass off from the cathode; if there are any positively-charged particles they will go off from the anode. While the cathode particles proceed in straight lines and strike at a given point, the anode particles would proceed in straight lines and strike at a different point. By a series of careful experiments carried out under the supervision of one of the German physicists, Lilienfeld has shown that these anode particles do strike the wall of the tube opposite the anode. A phosphorescent patch of light will be produced there. These anions, if they exist, should permit of being dealt with in the same way as the cathions. If we impress an electrostatic field we ought to be able to deflect them. By impressing the electrostatic field upon these rays, making it of such strength as to overcome the magnetic field, we should be able to determine the value of *e*. A remarkable thing is that from the ratio of *e* to *m* obtained for the anions, assuming that each carried one positive charge, as the cathion carries a negative, the mass of the anion was found to be about one-half to one-quarter that of the cathion. It is possible, however, that the anion or positive particle has the same mass as the negative, or again, they may have a mass only one-fourth as great. The experimental error is necessarily so great that we cannot decide between these possibilities.

We have taken up the negative electrons and the positive electrons, but have found nothing to suggest matter; nothing but the electrical energy, positive and negative. You may ask then, how it is that atoms of one substance differ from those of another substance? First, in the number of electrons present; second, in their arrangement; third, in the movements of the electrons. You know that the different chemical elements have mass and energy; each element having its own definite amount of intrinsic energy, part of which can be converted into heat. The electron theory accounts for all this. We know something of the number, arrangement and movement of these electrons; and their different arrangements and combinations give the different atoms of the various elements.

One other question is that of the ability of the electron theory to explain certain well-known facts. We have had the theory of electric dissociation for a number of years, which is as well established as nearly any so-called law of nature. I have been criticized for that statement. I believe that there is as much evidence for the general correctness of this theory as there is for any other fundamental law of nature. But there has been one feature of electrolytic dissociation that has been troublesome: How does it take place? Take sodium chloride, throw it into water, and how does electrolytic dissociation take place? How does the sodium get a positive charge, and how does the chlorine get a negative charge? We had no means of determining this until we had the electron theory. See what takes place: The sodium gives off one negative electron to the chlorine; and thus the sodium, having given off one electron or negative charge, is charged positively, and the chlorine having gained one negative electron is charged negatively.

Take the subject of radio-activity: Try to deal with this subject in terms of any theory except the electron theory, and you will come out about where you began. The radium atom is unstable, as you know; it is breaking down. In the early stages it does not shoot off isolated negative electrons, but great groups of them; possibly three or four thousand are carried away as the alpha particles. After a time, the atom becomes more stable, due to these electrons being shot off, and the electrons begin to come off separately. Then when it grows old, these particles become still scarcer; the atom becomes more and more stable; becomes smaller and smaller; and finally the radium atom passes over into something, in all probability the element lead. An enormous amount of energy is given out by the radium atom, two or three million times as great as you can get from the most exothermic chemical reaction known. The phenomena of radio-activity can, for the most part, be explained by the theory of the electron and by nothing else, as Rutherford has pointed out in a most brilliant manner. The larger the number of electrons in the atom, other things being equal, the more unstable it is.

If we attempt to apply this theory to the Periodic System of the elements—which Thomson has done, and which time will not permit me to discuss in detail—we find that many of the otherwise purely empirical facts, without the slightest bit of physical foundation, can be accounted for and predicted by the electron theory. I think I have said enough to show you how the conception of the electron was developed experimentally; how to determine the mass of an electron; how the ultimate unit of all matter was at first supposed to be a corpuscle containing both matter and energy; how it was shown that the properties of the corpuscle can be accounted for by the electrical charge; and I have tried to make a few applications of the electron theory to a few fundamental facts of science.

The old conception, of the chemical atom of one substance being something *fundamentally different* from the atom of another elementary substance, is gone. The atom of one substance differs from that of another chiefly in the number, arrangement, and velocity of the corpuscles present. Atoms fundamentally considered are the same. And finally, the older conception that the chemical atom is a stable, unchanging system must be abandoned. We now know that at least some of the elements are undergoing a devolution—a breaking down from the more complex into the simpler. This is the exact reverse of the processes of evolution in the organic world, which are building up the more complex out of simpler material.

This is sufficient for one evening. We all know that these are great times in which to live from the standpoint of investigation. Erroneous or insufficient conceptions are yearly giving place to broader and truer generalizations. The velocity with which the wave of knowledge is moving is ever increasing. This is made possible by the work of the investigator, without which all progress in knowledge would cease.

LARGE SHELL TYPE TRANSFORMERS

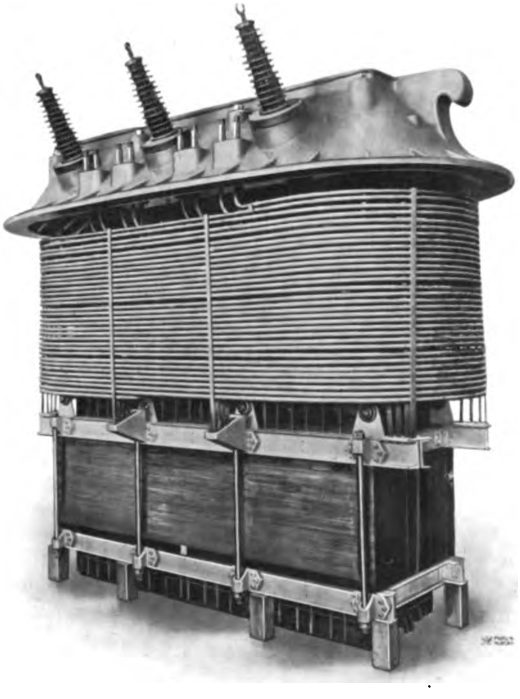
By E. R. Pearson

The increasing demand and broadening field for the transmission of electrical power, and the consequent necessity for the development of large high voltage apparatus to economically supply energy over great distances, has resulted in the manufacture, by the General Electric Company, of the largest and highest voltage transformers ever produced.

10,000 Kw., 60 Cycle, Three Phase Transformer; 100,000 Volts Primary, 11,000 Volts Secondary

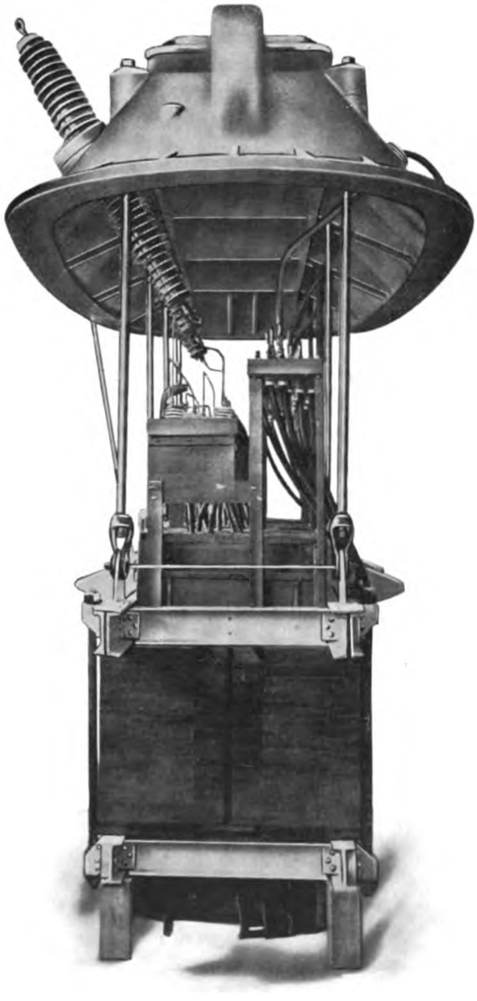
Until within a short time the highest voltage transformers regularly built for such purposes seldom exceeded 60,000 to 70,000 volts, with a few isolated cases of operation at 80,000 volts; the greatest demand being for 60,000 to 65,000 volt apparatus.

In comparison with the foregoing, the General Electric Company has, within a few months, shipped from its works many large shell type transformers having a high tension voltage of 100,000 and over.



10,000 Kw. Transformer with Cooling Coils in Place

A notable installation is that of the Central Colorado Power Company, which is just putting into service some water cooled, 60 cycle, 400 kw. transformers, of 90,000 volts high tension to 13,800 volts low tension; and several 1500 kw. units of the same frequency and voltage.



10,000 Kw. Transformer Removed from Case

A number of 750 kw., 60 cycle, 100,000 to 525 volt, and 104,000 to 4,000 volt transformers of the same type have also been constructed for the Stanislaus Power Company, Vallecito, Cal.

The feature of special interest in this apparatus is the unusual voltage for commercial duty, and much attention was necessary for the proper selection and distribution of the insulation, which was required to withstand the regular high potential and double voltage tests; this it did most successfully.

Besides these transformers, which are exceptional with respect to their voltage, the General Electric Company has produced the largest ones yet manufactured. Thus, within the past two years or so, several 25 cycle, 7500 kw., 60,000 to 13,200 volt transformers, of the forced oil type, in three phase units have been furnished to the Great Northern Power Company of Duluth, Minn. These have been described in the May, 1906, issue of the REVIEW, and up to that time were the largest transformers ever built. Since then, however, the Company has built some 60 cycle, 100,000 to 11,000 volt three phase water cooled units which are even larger. These transformers, which were constructed for the Great Western Power Company, Feather River Installation, are so large that they cannot be transported complete, but must be partly disassembled for shipment, including the separation of the tank itself.

The illustration on the cover of this issue shows one of these transformers with tank and cooling coil removed. It also shows the method of suspension from the cover.

The Great Northern Transformers require an approximate floor space of 6 ft. by 14 ft., the height being about 16 ft.; while the Great Western Power Company's units have a floor space of approximately 9½ ft. by 18 ft., with a height of approximately 18 ft. The net weight of the former, without oil, is about 85,000 pounds, and that of the latter about 120,000 pounds; while the wire used in the primary of larger unit is approximately ten miles in length. The oil required is about 4000 and 7500 gals. for the two sizes, respectively.

The full load efficiencies are nearly 99 per cent. in each case, and are probably the highest yet obtained, particularly for such exceptional voltages. Although the losses are only 1 per cent., yet this represents 125 horse-power, in the case of the Great Western transformers; a fact which gives one an idea of the magnitude of the units from another view point.

The high tension terminals for all these transformers, with the exception of those for the Great Northern Power Company, required special consideration, and for the first time, an oil filled lead was used. This lead was recently developed in the transformer department, but had not, up to this time, been used commercially, except for high voltage testing transformers.

A WELL LIGHTED OFFICE

By B. G. Worth, Jr.

At 31 West 32d St., New York City, a model lighting equipment has just been installed in the office and warerooms of the Brunswick-Balke-Collender Company, by the engineering-construction organization of Walter Kidde. The artificial illumination of this office was designed to approach daylight as nearly as possible, and the comments of observers attest that the desired result has been accomplished.

The opinion is frequently put forth that artificial lighting cannot be economical and at the same time harmonize with its architectural surroundings, both as to purely light effects and also as to fixtures. The above installation, however, proves that not only can the lighting effects be made to harmonize with, but also to emphasize the decorative effects, and this without sacrifice of economy.

Another interesting feature of this installation is the fact that it is a new departure in the line of incandescent lighting. Heretofore incandescent lamps have been used with shades or globes. In this case a new system of lighting was evolved, the direct propagation of light being discarded, and the principles of diffused lighting, which have already proven so useful with arc lamps, being applied to incandescent lighting with splendid results.

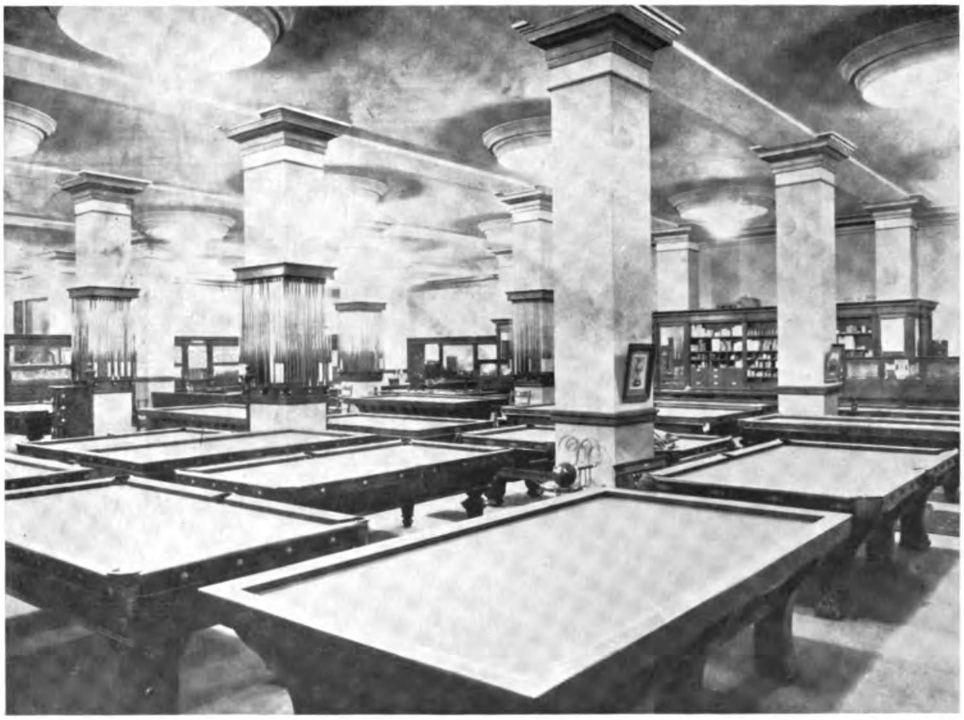


Fig. 1. First Floor, Brunswick-Balke-Collender Co., Lighted by Arc Lamps fitted with Light Balancing Selective Ceiling Diffusers

In order to produce harmony in any lighting installation, certain features should be observed. The fixtures must correspond with the style of architecture and decorations, the light effects must be such as to emphasize the scheme of proportions, and the lighting itself should be subordinated so as to attract little attention. In this particular instance a light of high illuminating power was required, so as to exhibit to the best advantage the beauties of the dark woods shown; and, as the sales room is of large area and the articles of sale of various shapes, a high degree of diffusion and a very uniform illumination were also required.

The warerooms consist of a first floor and a basement, as shown in the floor plans (Figs. 3 and 4). The height in the clear of the first floor is approximately 16 ft.; that of the basement is 11 ft., 6 in. The first floor receives a certain amount of light during the day from a skylight in the rear. At the time the building was turned over to the tenants, the rooms had been completely wired and provided with switch panels of the usual type. The old wiring was based on an allowance of about 330 watts per bay (approximately one watt per square foot) for the first floor, and about one-half of this for the basement. Direct current was available, supplied from the 120 volt three-wire system of the New York Edison Company.

For the first floor, arcs were selected, as the most efficient illuminant and in view of the high ceiling. In order to make use as far as possible of the wiring already installed, the lamps were arranged two in series across 240 volts, 6½ ampere lamps being used because of the superior steadiness of an arc of this amperage and its absence of color. Some hesitancy was felt regarding this arrangement, lest the arcs might have a tendency to flicker, but on the guarantees of the manufacturers this was over ruled; and it may be said here that the operation of these lamps has been strikingly free from flickering, and has entirely borne out anticipations. The necessity for uniformity of illumination induced the selection of the General Electric Light Balancing Selective Diffuser. (Fig. 5.) This diffuser consists of an arc lamp beneath which is hung a slightly translucent tulip shaped shade. Around the arc lamp is an inverted, conical, sheet metal reflector, and beyond this again an annular ring, or corona. All reflecting surfaces are dead white. A slight amount of light penetrates the shade, the remainder being reflected against the cone and then against the corona, thus breaking up and diffusing the rays, the curves of the reflecting surfaces of the diffuser being calculated to

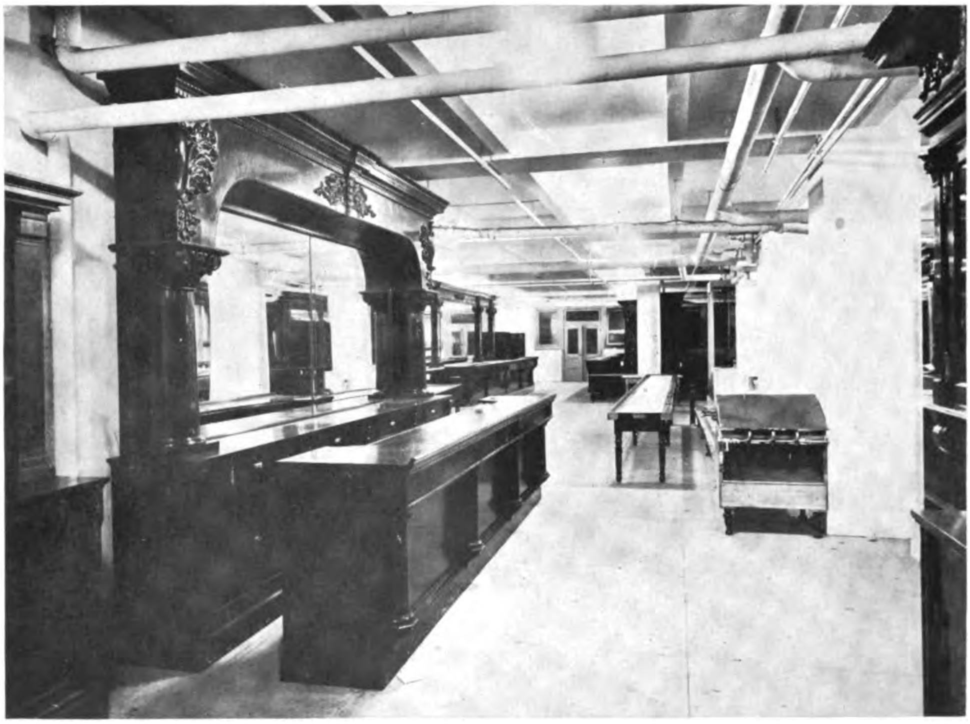


Fig. 2. Basement. Lighted by Tungsten Lamps fitted with Extension Diffusers

distribute the light rays uniformly. The diffuser is usually constructed altogether of sheet steel, but in this case the coronas were made of plasterstaff, being designed to match the capitals of the columns. The fact of the ceiling being already built made necessary the use of the projecting type of diffuser, reducing to 14 ft. the distance from the tip of the lower shade to the floor. The arcs are located in the centers of bays, as shown, except those over the general office, where more light was required. Twenty-six arcs are installed in this section and are controlled in pairs from the distributing panel. The first floor is finished with light green walls with maroon base and cream ceiling. The floor is covered with brown cork linoleum. The woodwork is mission finish.

Arc lamps could not be used in the basement because of the low ceiling, and because it was desired to be able to throw the entire light off when not in use for displaying goods. It was therefore decided to use incandescent lamps. Due to the cost of current (10 cents per kw. hr.), tungsten lamps were selected. The tungsten filament, however, had too high an intensity of emission to be used for direct lighting in this case, and even with the lamp bulb frosted the intrinsic brilliancy of the unit was too great for the best results under the conditions here existing. Under these circumstances no standard fixture was suitable, and to meet such conditions the Extension Diffuser was developed by the General Electric Company (Fig. 6). The diffuser used consists of an elongated, annular, ornamental cast bronze frame, carrying an inverted, bowl shaped, white, pressed steel reflector or diffuser. Three 100 watt clear tungsten lamps are placed in a line down the center of the frame and beneath the diffuser. Beneath these lamps is held an elongated, deep, leaded glass shade, slightly translucent, which entirely conceals the lamps and reflects most of their light against the steel diffuser, from which it is distributed throughout the room. These fixtures fit directly against the ceiling, making the height from the tip of the shade to floor, about 10 ft., 9 in. The irregularity of the basement is such that no attempt at a symmetrical arrangement of the fixtures was made. Twenty-five fixtures are installed in this section. Except for one fixture, all the lamps in the basement are thrown on and off by a solenoid switch at the distributing panel, controlled by a push button master switch located at the foot of the stairs leading from the first floor. In addition to this, fixtures may be controlled in pairs from the distribut-

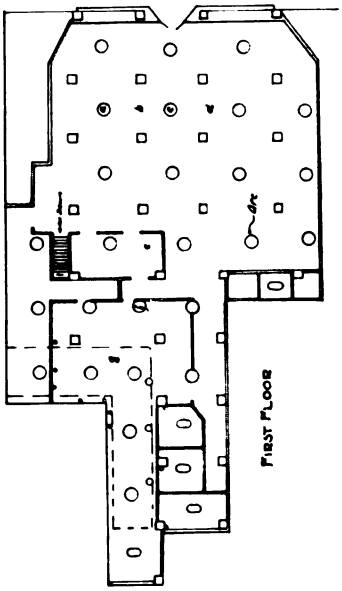


Fig. 3. Plan of First Floor

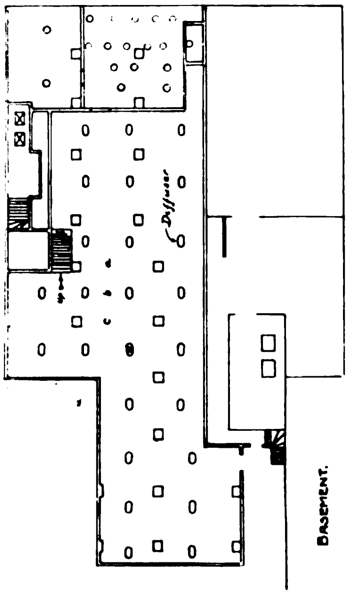


Fig. 4. Plan of Basement

ing panel, and a master switch is located at this point also. The basement walls and ceiling are finished dead white; while the floor is of concrete finished in gray paint.

The private offices in the rear of the first floor are lighted with Economy diffusers with tungsten lamps. These diffusers (Fig. 7) are very similar in principle to the train light diffuser and also give a soft distributed light.

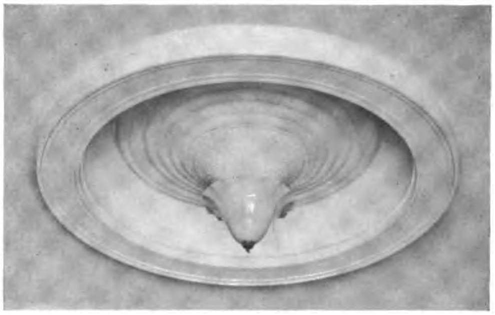


Fig. 5. Light Balancing Selective Ceiling Diffuser

There are no special arrangements for lighting the show windows. These windows extend across the whole front of the store and up to the ceiling. The effect of the interior illumination is such, however, that the entire front half of the store is virtually a show window.

A small shop in the front of the basement is devoted to ivory turning and cue making, and there is also a large re-enforced concrete ivory vault at this point. The shop and vault are lighted with individual, 40 watt, frosted, tungsten lamps in frosted bowl holophane shades. The shop is driven by a motor, all shafting being located on the floor; and an exhauster system is supplied for carrying away the dust and chips from the lathes and for ventilating the ivory vault. Ventilating fans are also provided in the main office, delivering through air shafts near the skylight.

The shop is lighted in the daytime by a sidewalk vault. Underneath this vault is placed a frame carrying glass prisms which distribute this light throughout the shop. A large frame of prisms is also used under the skylight in the rear of the main office, and throws light into the interior. These prisms are the means of a considerable saving in current, and it has been found that the daylight from the prisms and the arc light agree perfectly, so that it is impossible to notice any difference in passing from one to the other.

The distribution panels provided when the building was erected, were unsuitable for the new lighting because of the larger number of circuits required. At the same time it was desired to make use of the trim, wall box, etc.; the panels were therefore rebuilt more compactly. In the first floor panel, shown in Fig. 9, the upper buses are the 240 volt arc circuits; while the lower are the neutral and two outsides for the three wire Edison system. By the use of push button switches, by eliminating the main switch which is unnecessary, and by arranging the bus bars so that all fuses of one polarity are grouped together, it was possible to get all the new circuits (about twice the former number) in the old panel spaces and use the old trim, etc. As the cast iron door covering the fuse compartment is usually closed, the fuses are not exposed except when it is necessary to replace one; it is therefore possible to manipulate the panel switches in the dark without danger of shock. Also a fuse may be replaced with a great deal of confidence when the panel is live, as no risk is run of touching a conductor of opposite polarity. This is a great advantage, as the whole room does not need to be darkened every time a fuse blows out.

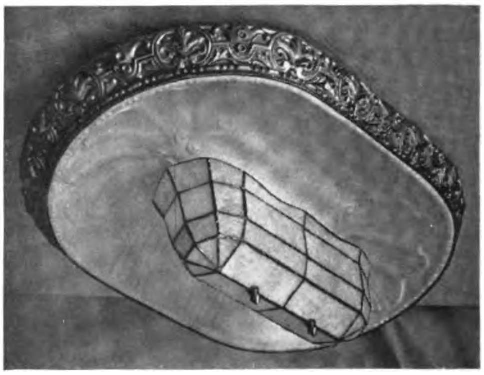


Fig. 6. Tungsten Extension Diffuser

An examination of the photographs of the first floor and basement (Figs. 1 and 2) will show the excellent results obtained as far as diffusion is concerned. These negatives have not been retouched. The lack of dense, well defined shadows and the perfect lighting of all surfaces, whether facing the fixture or not, is very striking. In the picture of the basement, it will be noticed that underneath the table the illumination is just about the same as in the open, and that the pipes near the ceiling cause no shadows, although some are directly under the fixtures. Another noteworthy feature is the subordination of the lighting and fixtures. The intrinsic brilliancy of the light source is so low, that the eye is not particularly attracted to the light in preference to the decorations. It is even quite possible to look directly at the light without the image persisting when the eye is turned away again. At the same time these results are obtained without sacrifice of brilliancy, as the grain of the wood may be seen distinctly, and all the details of carving stand out boldly.

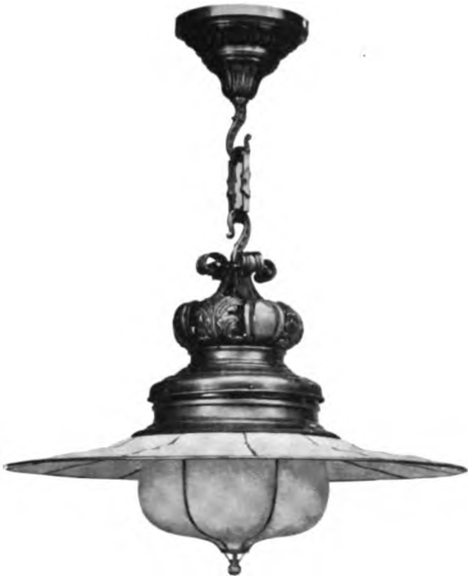


Fig. 7. Tungsten Economy Diffuser Chain Suspension

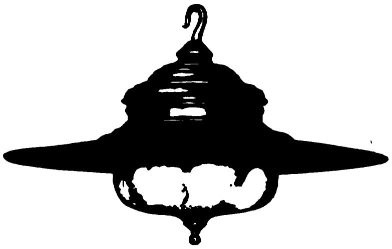


Fig. 8. Tungsten Economy Diffuser Ring Suspension

The color of the light is very satisfactory, the arc light being almost entirely free from color, and the tungsten lamps in the basement, with the white walls that are used, producing a general effect that approximates daylight very closely.

Fig. 9. Panel Switchboard

The exact intensity of illumination, as measured with a Ryan Luximeter, is given below; the locations being shown in plans.

First floor, plane of readings 39 inches above floor.

Stations (a) . . .	4.25 candle feet
(b) . . .	4.65 " "
(c) . . .	5.00 " "
(d) . . .	4.65 " "
(e) . . .	4.65 " "
(f) . : .	5.90 " "
(g) . . .	5.60 " "
(c) with all other fixtures out	3.00 " "

Basement, plane of readings 39 inches above floor.

Stations (a) . . .	1.75 candle feet
(b) . . .	2.80 " "
(c) . . .	1.90 " "
(d) . . .	4.90 " "
(d) with all other fixtures out	2.60 " "

The remarkable uniformity of illumination for the first floor will be noted. The illumination of the basement is not so uniform, due to the low ceiling. The current consumption for the first floor averages 2.78 watts per square foot for the entire area, the average intensity being 4.69 candle feet. The current consumption for the basement averages 1.37 watts per square foot for the entire area, the average intensity being 3.20 candle feet. The apparently higher efficiency of the incandescent lighting is due, of course, to the lower ceiling and its dead white finish. In addition to this, the basement walls are white and there are a large number of mirrors. Also in addition to the high ceiling of the first floor, about 20 per cent. of the wall area is clear glass, which reflects very little light, and, of course, the green paint absorbs considerable light.

It is of interest to note that tests made in the basement before any furniture was introduced, show intensities of illumination about 50 per cent. greater than at present. This shows in a remarkable way the great amount of light which is absorbed by the interior fittings of a room, and how necessary it is for the engineer to make allowance for the character of these fittings when designing the lighting system.

In closing, it may be said, that it should be a subject of mutual congratulation among electrical engineers, that recent development in diffused lighting by both arc and incandescent lamps has made possible so successful an installation as the above. The various means of utilizing electrical energy as an interior illuminating agent have been decidedly unsatisfactory. Now, however, thanks to the diffuser idea, there are solutions for all problems, ranging from a single room, lighted with one lamp in a modified extension diffuser, or by an Economy diffuser, to the largest hall lighted with diffuser type arcs, and at that lighted economically, artistically, and with effects which are so close to daylight as to be practically the same.

THREE-POSITION AUTOMATIC SIGNALS ON THE BALTIMORE & OHIO RAILROAD

By F. B. Corey

During the past two years, the Baltimore & Ohio Railroad Company has installed and placed in service on its various divisions approximately 300 three-position electric motor signals and about 400 relays, all of General Electric manufacture. The greater part of these signals are of the M-110 type, the remainder being of the M-210 type. These types differ only in that the former is arranged to move the signal blade in the *lower* right-hand quadrant, while the latter operates the blade in the *upper* right-hand quadrant. This difference in design is clearly seen in Figs. 1 and 2, which show the various indications of the two types. Forty-eight signals of the new arrangement (Fig. 2) have recently been put in service.

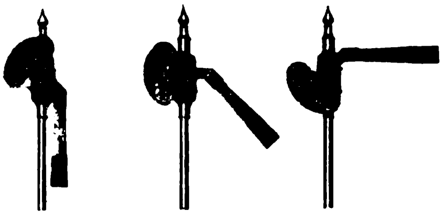


Fig. 1. M-110 Electric Motor Signal on B. & O. R. R. Standard Lower Quadrant Semaphore Spectacle

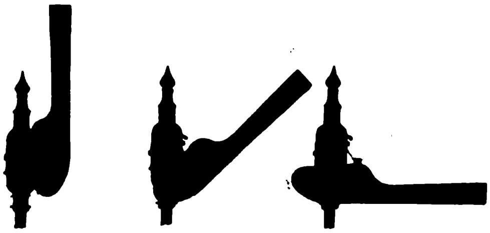


Fig. 2. M-210 Electric Motor Signal on B. & O. R. R. Standard Upper Quadrant Semaphore Spectacle

At the time General Electric signals were adopted by the officials of the Baltimore & Ohio R. R., this was the only three-position top mast semaphore signal on the market. Some of the reasons for the adoption of this type of signals by such an important railroad may be of interest.

The direct application of power to the semaphore shaft avoids the necessity of changing from a rotary motion to a straight line motion and *vice versa*, in order to transmit power from the bottom to the top of the mast. This arrangement, therefore, permits a simplicity, rigidity, and compactness in design that cannot be secured with any other location of the motor mechanism. On account of this construction, the insulation of the entire mechanism and case from the mast becomes an easy matter, and thus a large percentage of the troubles due to grounded wires is avoided. Up-and-down rods, with their jaws, pins and guides, are unnecessary, and the friction of such parts is entirely avoided, thus very considerably reducing the power consumption. All moving parts of the signal being contained in, or attached to, the mechanism case at the top of the mast, the signal can be installed with a minimum of labor on any kind of a pole. This feature is especially valuable in temporary installations or repair work, as the signal can be easily placed on a pole and wires run to the proper terminals in the case, when the installation will be complete. The locating of all moving parts at a distance from the ground, lessens the liability of dirt accumulating inside the mechanism case. This construction also obviates any difficulty from floods and surface moisture.

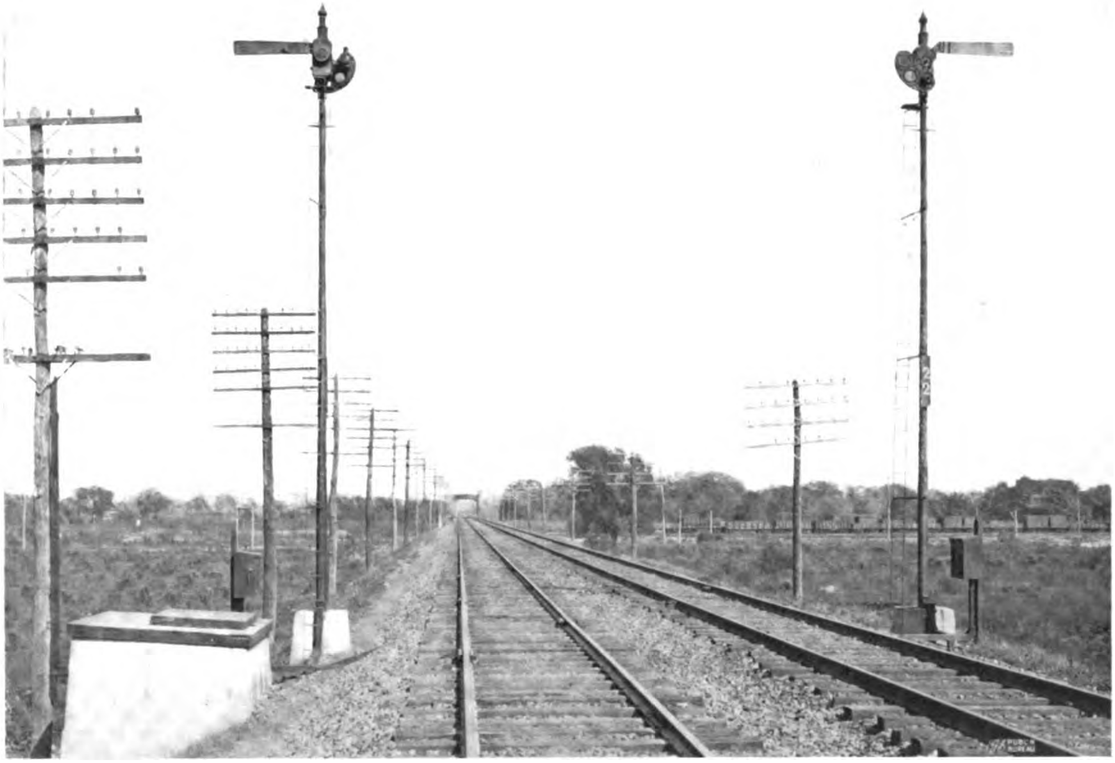


Fig. 3. M-110 Electric Motor Signals on Straight Masts, B. & O. R. R.

On the main line of the Baltimore & Ohio Railroad, between Baltimore and Washington, all traffic is controlled by automatic signals of the M-110 type. Part of these signals are installed on straight masts, as shown in Fig. 3, while the others are on bracket masts, as shown in Fig. 4.

From January 1 to December 31, 1907, an accurate record was kept of the total expenditures connected with 25 automatic signals on the main line between Baltimore and Relay, Md., which were placed in service about the first of July, 1906. These signals averaged over 125 operations per day. During the year the cost of operation and maintenance, including all labor and material for signals, lamps and batteries, with 5 per cent. depreciation and 5 per cent. interest charges, amounted to 48 cents per day per signal. When it is noted that these are three-position signals (equivalent of two two-position signals) it seems that the cost of such electric motor signals is small, considering the high degree of safety and increased capacity of traffic secured.

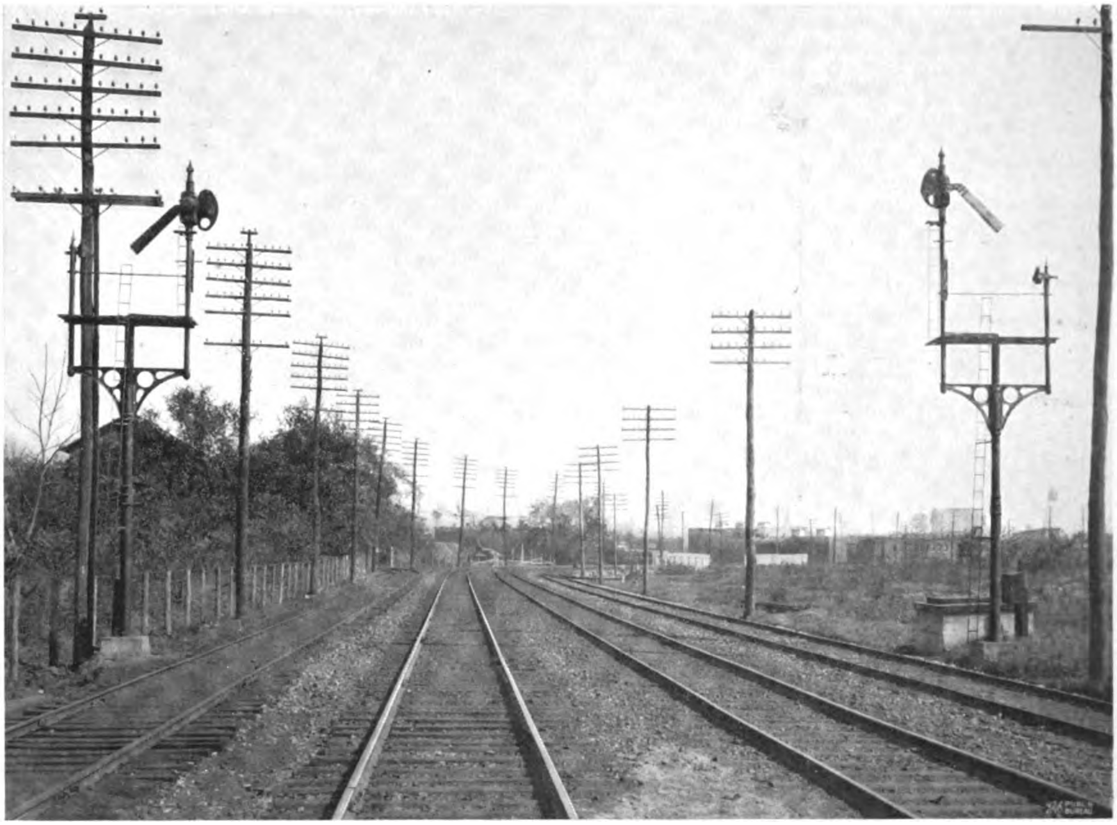


Fig. 4. M-110 Electric Motor Signals on Bracket Masts, B. & O. R. R.

An interesting feature of this installation, which, however has been used elsewhere, is the method of power supply. Each signal is provided with six cells of storage battery connected in series. Across the terminals of this battery are placed eighteen cells of gravity battery, which serve to keep the storage battery continuously charged. The gravity battery is easily maintained, and under these conditions the storage battery needs but little attention.

In some of the later installations, the signal lamps are operated from the battery, three extra cells of gravity battery being used across the storage battery to carry the additional load. In order to obtain this high degree of efficiency, the lamps are lighted only when a train is approaching the signal. A diagram of the connections used was shown in the Review for September, 1907, page 158.

The operation of these signals has given the greatest possible satisfaction to the Railroad Company.

ELECTRICITY IN GAS PLANTS

By J. S. Knowlson

The utilization of electricity both for illuminating and power purposes, in the widely divergent fields of industrial work, has grown so rapidly during the past few years that one scarcely experiences even passing surprise when different applications are brought to notice. However, the use of electricity in the modern processes of gas manufacture is not only interesting in itself, but the bare fact that it is so used must bring a subtle feeling of satisfaction to those who have watched the struggle between gas and electricity for supremacy in the field of artificial illumination. While this struggle has gone on through the greater part of the past decade, there is no question to-day but that electricity for illuminating purposes is not only safer, cleaner and more hygienic, but also cheaper; particularly since the recent introduction of the tungsten lamp. However, it is none the less true that gas has found great favor as a convenient and cheap fuel, and it is probably along these lines that its use will increase rather than diminish.

"Good practice demands that an open light should never be used in a gas plant. Failure to regard this rule has probably resulted in more fires and explosions in gas plants than any other cause," writes one of the most prominent gas men in the country, and this statement of fact in a nutshell explains why the modern gas works install electricity for illumination. In the purifying houses, where the slightest spark or open flame engenders great danger of explosion, the incandescent lamp is practically the only one which fulfills conditions necessary for safe operation. In other portions of the works and in the yards, which are often of considerable magnitude, either arcs or frequent incandescent lamps are used.

For power purposes, the usual arguments for electric drive carry great weight. Not only may numerous small and inefficient steam units be replaced by motors, but also long runs of steam piping, with all attendant losses, may be superseded by electrical transmission, the losses of which may easily be considered negligible.

The large gangs of unskilled labor which were necessary in the older and more primitive plants for unloading coal, transporting it in small dump cars to retorts, and carrying away coke, ashes, etc., are replaced by electrically driven conveyors, doing the same work more quickly, more cheaply and better.

In one plant delivering 1,500,000 cubic feet of coal gas and 750,000 cubic feet of water gas per day, manual labor is reduced to a minimum.

The coal is conveyed from the cars to storage by electrically driven conveyors. From the storage it passes to crushers, also electrically driven, and after passing through them, another conveyor, driven by a 10 h.p., 750 r.p.m. induction motor, carries it to the bins in the retort house. The coke and ashes are removed from the retort house to the dump by one conveyor, the ashes being removed on the lower floor and discharged at one end of the building, while the coke is taken care of on the return trip of the conveyor chain on the upper floor, and discharged at the other end. From the dump, the coke is carried to the water gas house, boiler house, or coke pile, as the case may be, by a telpher and a 3600 lb. grab bucket. This telpher has a 25 h.p. D.C. motor for hoisting, and a 15 h.p. motor for traveling.

One of the most striking examples of the advantages of electric drive is found in the machines for charging the retorts. Two machines, each equipped with one 5 h.p. and two 10 h.p. induction motors, charge twenty retorts of 600 pounds of coal each, in fifteen minutes. The old method of hand firing required a large gang and often several shifts, as the extreme heat above the retorts made it impossible for the men to work for more than a short period at a time. With the new machinery, all operating is done from a distance, and the operator is not subjected to the direct heat from the retorts.

The blowers and pumps, formerly driven by steam or gas engines, as well as the machinery in the repair shop, are all electrically driven. In the purifying house, the most dangerous place in the works, the traveling crane, equipped with a grab bucket, is operated by a 40 h.p. induction motor. The starting compensator for this motor is located in the generating station, and the three motions of the crane and the grab bucket are controlled by clutches, in order to avoid any danger of sparking.

This is an example of but one of many plants that are now electrically equipped. The size of the equipment depends upon the capacity of the plant. As a general rule, it may be stated, that 0.1 to 0.125 kw. generating capacity will have to be installed per 1000 cubic feet of gas generated per day, but as a large proportion of the service demanded from this generating equipment is of very intermittent character, half of this capacity may be looked upon as spare apparatus.

The power consumption will average between 0.885 and 1 kw. hours per 1000 cubic feet of gas produced. This figure includes current for lighting and complete power equipment.

The plants at Everett, Worcester, Lowell, Mass., New Haven, Conn., and Lynchburg, Pa., while they by no means stand alone, present excellent examples of modern well equipped gas plants.

Today public service companies, delivering both gas and electricity for commercial purposes, have installed electric light and power equipment, at least to some extent, in their gas plants.

The independent gas companies, however, are only beginning to realize the economy which is to be derived from such installations. Every gas plant, whether it generates coal or water gas, must need have installed boiler capacity, if only to obtain the low pressure steam necessary in the manufacturing of the gas, and to keep their holders from freezing in winter. This existing boiler capacity materially reduces the first cost of the electrical equipment, and the fact that those gas plants which have already installed electricity report savings of from 25 per cent. to 50 per cent. in the cost of generating, and even a greater percentage decrease in repairs. is having great effect upon the rapidity with which existing gas plants are being equipped with electrical machinery.

With the increasing realization of the necessity for efficient and economical production of gas, so that it may compete successfully in the fields of household fuels, it is safe to state that within five or at least ten years, one will scarcely find a gas plant in the country which does not use electricity for both power and illumination throughout

ELECTRICAL EQUIPMENT OF THE ANHEUSER-BUSCH BREWERY

By William Hand

Brewing business carried on without the use of electricity would meet with little success in competition with the most modern equipment. Some concerns achieve greater success than others, due principally to the foresight of the management in employing the most modern and efficient method, which gives a better product at less cost. Such is the case with the Anheuser-Busch brewery, one of the largest in the world. The size of the plant is given below, together with data relative to equipment and capacities, so that a clear understanding may be had of the enormous business done; the growth has been steady and firm.

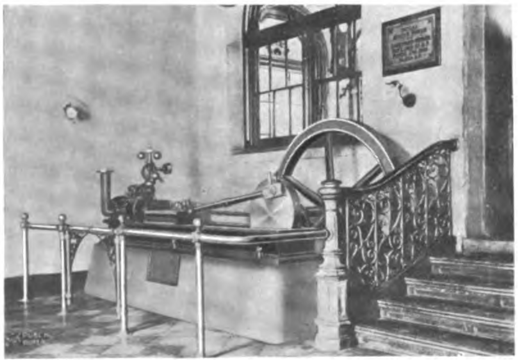


Fig. 1. 25 h.p. Slide Valve Engine. Initial Motive Power of Anheuser-Busch Brewery

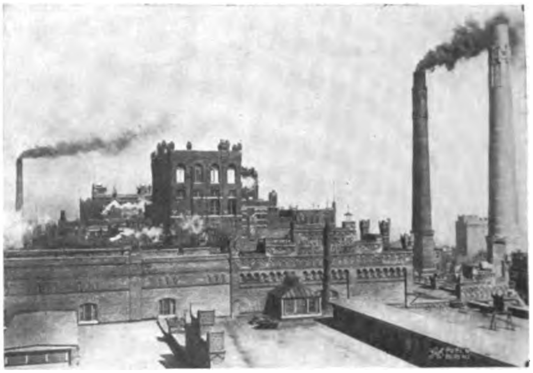


Fig. 2. Tops of Buildings as seen from Stock House No. 10

Electricity was first employed immediately after the electric motor was pronounced a success, the old Edison Companies furnishing the first equipment in 1885. Since then the General Electric Company has installed the major portion of all the electrical apparatus employed.

Buildings, Capacities, etc.

The brewery covers 142 acres.

The large barley cleaning house, which receives the grain from the railroad, has a capacity of 20,000 bushels per day.

Malt houses, 9,800 bushels daily.

Brew houses, 9,800 bushels daily.

Grain elevator storage, 1,750,000 bushels.

Stock houses or storage, 1,660,000 bbls. beer.

Ice and refrigerating plants, 4,000 to 5,000 tons daily.

Bottling departments, 1,120,000 bottles per day.

Employees, 5,000 to 6,000.

Electrical Equipment

There are two generating plants centrally located, about 1200 feet apart. The system is 3 wire, 110/220 volts direct current. Both steam plants operate condensing, with about 27 inches vacuum, at a steam pressure of 140 pounds.

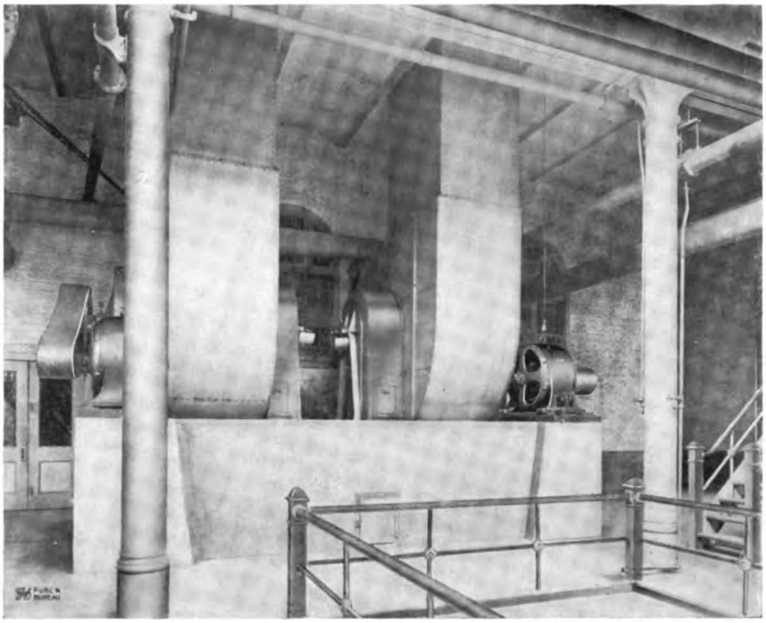


Fig. 3. Two CL 6-35 h.p. 610 r.p.m. Motors, Driving 4 ft. by 11 ft. Suction Fans

No. 1 power house is equipped with two 500 kw., 90 r.p.m., 250 volt General Electric compound wound generators, each driven by a vertical cross compound engine; and two 300 h.p. steam turbines, each driving two 100 kw., 900 r.p.m., 250 volt compound wound generators.

The neutral for this power house is established by two balancer sets, one a 45 kw., and the other a 20 kw. machine.

No. 2 power house contains two 500 kw., 90 r.p.m., 110/220 volt, 3 wire generators, and operates in multiple with power house No. 1.

Four hundred and forty-six motors are in use throughout the brewery, aggregating 4747 h.p. About 900 h.p. will be required in addition to this to complete the electric drive of all the machinery. The generating plants are large enough to furnish this extra power.

Table I (page 185) gives a list of the principal buildings, and the number and range in sizes of motors employed in each.

Table II (page 186) gives the location of the principal motors, the size, speed and class, and the work performed by each.

Description of Beer Making Process

A brief description of the routine the barley goes through, after it is received from the railroad until it is malted and made into beer ready for the market, is as follows:

The grain is received first at the barley cleaning house, where 6 cars can be dumped at one time. Grain elevators, electrically driven, carry the grain to the eighth floor, where it is weighed and passed on through the separating and cleaning machines, which automatically clean and separate the grain into 3 grades. It is then transferred by elevator and conveyors to steep tanks in the malt house, or put in storage in the grain elevator.

Barley can be taken direct from the cleaning house or grain elevator, to steep house. 60 to 70 hours are required for steeping, depending upon the temperature of the water. When the steeping process is completed, the grain is dumped into ærating revolving malting drums on the floor below.

Six days are required to complete the germinating, after which the malt is carried by conveyors and elevators to the kiln floors, where it is dried 48 hours and then dumped to hoppers below. From here it is taken to the cleaning machines and then to the malt storage elevators. The malting process is now completed and the malt can be kept stored indefinitely. The malt is taken as required from storage to brew house by conveyors. Each grade is ground separately, and separately carried from mills to mesh tubs, from mesh tubs to steaming tanks, and thence to copper cooking kettles, where the hops are added. There are 7 of these kettles, each holding 400 barrels. The cooking requires about 3 hours. Centrifugal pumps are employed for pumping the beer from the cooking kettles, over and up to the cooling ship on the ninth floor of stock house No. 7, where it is cooled from about 200 to 40 degrees. From the cooling ship, the beer is conveyed by gravity to the various stock houses or fermenting rooms. Two weeks are required for fermenting. When this process is completed, the beer is forced by centrifugal pumps to the aging cellars. Three to four months are required for aging. The beer for bottling is kept here under Government lock until the revenue stamps are purchased. It is pumped from these cellars to the various bottling and kegging departments, then to the shipping department, ready for market.

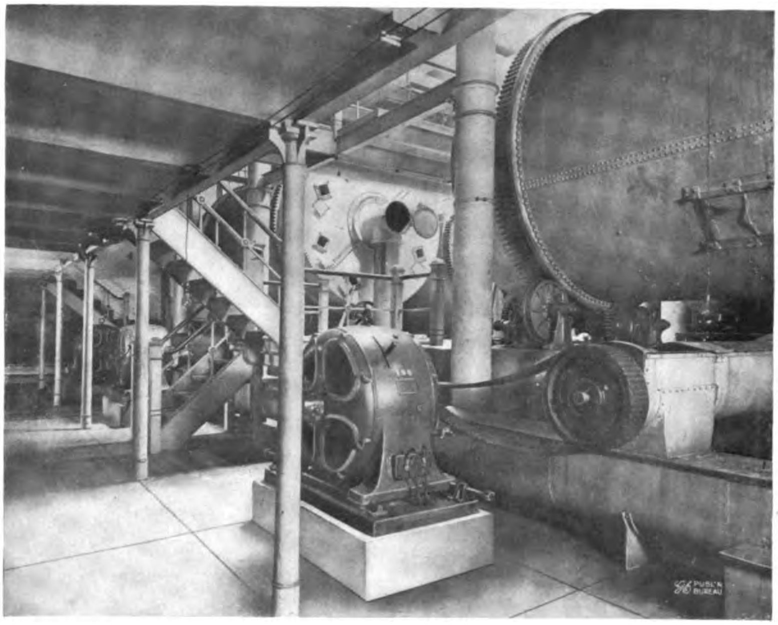


Fig. 4. 25 h.p. Motors Driving Malt Conveyors

Initial and Present Motive Power

Fig. 1 illustrates a small 25 h.p. slide valve engine which was in operation in 1866, this engine being the total motive power required for the brewery at that time.

The illustration on page 146 shows one of the 500 kw. units in power house No. 1. This room has white enameled brick walls and ornamental tile floor. The equipment is in strong contrast with the initial unit in operation 42 years ago.

Fig. 2, which was taken from top of stock house No. 10, shows in the right foreground the tops of the two large smokestacks from power house No. 1. In the left background is a large stack of the bottling works, and in the middle center is stock house No. 9 and the cooling ship. In the rear of the stock house to the right is the large brew house, only the tops of the buildings being in view, which are from six to nine floors above the street level.

Barley Cleaning House

The size of this building is 100 by 50 feet, eight stories in height. The unloading department is adjoining. Thirty-two motors are employed here, aggregating 520 h.p.

Malt Houses

There are four malt houses, but most of the work is done in the two large new houses, one of which is driven by motors, the other by engines. There are 32 motors aggregating 705 h.p. in the motor operated malt house. Steeping, germinating, and attemperating, and the completing of malting is done in the one building, which is 112 feet wide by 162 feet long, consisting of 2 stories and basement.

Grain is brought by elevator and conveyor from the various grain elevators and dumped into large steep tanks on the top floor. There are 30 of these tanks, each holding 610 bushels, with hopper shaped bottoms and with valves for dumping the grain. The water enters the tank from the hopper bottom and overflows at the top. All impurities are thus brought to the surface and carried away; air is also used when the tanks are first filled and just before the grain is dumped. As stated before, 60 to 70 hours are required for steeping. Water is changed 5 times during each steep.

When the steeping is completed, the grain is dumped into large revolving pneumatic malting drums on the floor below, where the

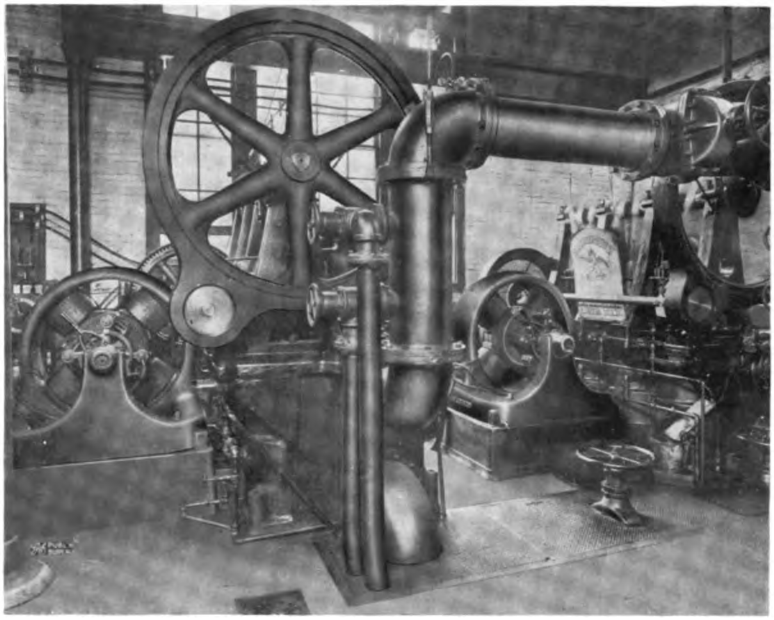


Fig. 5. Two 50 h.p., 515 r.p.m. Motors Driving Worthington Pumps

process of germinating and attemperating is carried on for 6 days. There are 30 of these drums, each having a capacity equal to that of the steep tank immediately above, or 10 bushels. The drums revolve very slowly about one revolution per hour, and during this process air is brought from the attemperating room and passed into the drum at one end. The air is then distributed through different portions of the grain separately, entering a large flue and passing out at the other end of the frame on to the large pressure blowers, which force it up to the roof.

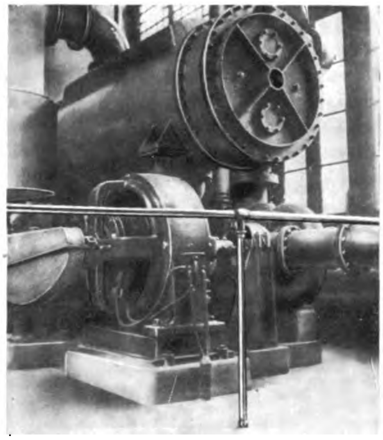


Fig. 6. 40 h.p., 915 r.p.m. Motor Driving Centrifugal Pump for Compressor

Fig. 3 shows a view of two CL 6-35 h.p. 610 r.p.m. shunt motors, each belted to one large suction fan, 4 by 11 feet. There are 3 of these units, each of the blowers drawing the air through 10 of the large malting drums just described.

The air first enters the building at the roof, passing through an area-way into the attemperating room, thence through area-ways to the drums, on to the fans, and up to the roof at the opposite end of the building from that at which it enters.

A unique method of passing the air into the drum and out is employed. The drums are supported by two large hollow bearing pedestals, one at each end of the drum, the drum axle also being hollow. Air passes up through the bearing into one end of the drum; but before the air can get out of the other end, it has to pass through a number of small square flues to one large center flue, then on out through the other bearing pedestal. The drum, revolving slowly all the time, automatically opens and closes the proper flues for admitting air.

Six motors, each of 10 h.p., 335 r.p.m., are required for revolving the 30 malting drums. Each motor drives a line shaft for turning 5 drums, the shaft and motor being located under the drums. The application is by chain belt from motor to shaft, and from shaft to drum by gear.

Malt Conveyors from Drums

Four 25 h.p., 410 r.p.m. shunt motors are connected by chain belts to the malt conveyors. Fig. 4 shows 3 of these motors. This system of conveyors takes the malt over to the elevator legs, which in turn convey the malt up to the kiln floors.

Two motors are in the basement, direct connected to centrifugal pumps, one being a 35 h.p., 1100 r.p.m. shunt machine furnishing water for cooling, the other a 25 h.p., 1100 r.p.m. compound wound motor driving a 3 stage pump for cooling, at a pressure of about 80 pounds.

Elevator & Kiln Department

The two large kilns, with stair house and elevator legs, join on to the two main malt houses—one for the electrically driven malt house, the other for the engine driven. The two kilns are of the 3 floor type, each being of the proper capacity to dry all the malt from the two large houses, the electrically driven malt house being slightly larger than the other. Both kilns are driven by motors. The size of the largest kiln is 90 by 90 feet; the other 70 by 72 feet. This does not include the dimensions of the stair house, which contains motors and shafting for operating the malt stirring machines, elevator legs, and ventilating fans.

The floors of the kilns are perforated steel dumping floors, with hoppers underneath. Artificial draft is employed. The malt is automatically stirred, and when the drying process is finished, which requires 48 hours, the malt is dumped into the hoppers below and then conveyed to the cleaning machines.

There are two other small kilns at a distant point which are used in connection with the two old malt houses.

Large Engine Driven Malt House

This building is approximately 200 feet long by 90 feet wide, 6 stories in height, and is equipped with 50 steep tanks and 50 malting drums, the process being carried on in a similar way to that of the electrically driven malt house, although the capacity of tanks and drums is less. This building also includes the rooms containing the malt cleaning machines.

Old Floor Malt House

This house has 12 steep tanks, with a capacity of about 2,000 bushels per day, the malting process being carried on, on the floor by hand method. One 25 h.p. motor, 1100 r.p.m., is employed here for driving drums, conveyor and fan.

Old Malt House

This house was equipped with 6 malting drums, which were the first of the kind at this brewery. The capacity of this house is about 1,000 bushels of barley per day.

Attemperating or Water Cooling Tower

This tower is located immediately across a narrow street from the No. 1 power house.

Fig. 5 shows two 50 h.p., 515 r.p.m. shunt motors installed in this building, each connected by a gear to a Worthington triple pump. The motors are arranged for armature speed control. The pumps have a combined capacity of 4,000,000 gallons for a 24 hour day, the water being used for cooling ammonia for the ice making plant.

Stock Houses

There are 10 stock houses in all, No. 10 being the largest, with dimensions of approximately 100 by 325 feet, 7 stories high. Five floors are equipped with large glass enamel lined tanks, including all necessary facilities, and making one of the most complete beer stock houses in the country. Approximately 380,000 barrels of beer can be stored in this building.

An air compressor is located on the third floor of this stock house and driven by a 20 h.p., 650 r.p.m. motor. The air from this equipment is used to keep up a uniform pressure in the large beer storage tanks while the beer is being drawn. About 17 pounds pressure is required.

Miscellaneous Buildings, Etc.

The wagon shop occupies a building about 125 by 225 feet, two stories high, each floor being divided into three rooms. One 30 h.p. motor, 550 r.p.m., drives 19 machines. Most of the brewery wagons are manufactured here.

The cleanings of the barley, and also those from the malt house, are carried to the Brewers' Dried Grain Company, where it is worked up into feed, and sacked ready for shipment.

The pump house is located on the banks of the Mississippi river, the filtering plant being close by, across the railroad tracks in the direction of the brewery. This equipment would be a credit to a good sized city; still, the water furnished by this station is only used in the brewery for power and washing purposes. The water used for making the beer is bought from the city.

Sixty-three large electric delivery trucks are employed, fifteen of 5 tons capacity and forty-eight of 2 tons capacity. The current required for charging all of these sets is taken from the main generating plant. These delivery trucks have greatly reduced the size of the stables; yet 160 horses and 50 large wagons are still employed.

Fourteen hundred special refrigerating cars are required to carry the product of the brewery to all parts of the United States. These cars are in addition to the regular local freight cars and other methods of delivery.

In addition to the large railroad terminal yards at the brewery, a manufacturers' railroad is also operated, employing 10 locomotives.

TABLE I

Building	No. Motors	Range in size
Barley Cleaning House	32	8 to 30 h.p.
Malt House	15	10 to 35 h.p.
Elevator and Kiln Dept.	14	10 to 50 h.p.
Old Floor Malt House	1	25 h.p.
Barley Storage Elevator C	2	15 h.p.
Malt Storage Elevator F	2	15 h.p.
Brew House	18	5 to 65 h.p.
Old Brew House	3	15 to 50 h.p.
Bottling Dept.	202	1/4 to 25 h.p.
Water Cooling Tower	5	25 and 50 h.p.
Power House No. 1	11	6 to 50 h.p.
Water Filter Plant for Beer	6	7 to 20 h.p.
Refrigerating House	5	10 to 40 h.p.
Stock Houses	39	1 to 25 h.p.
Machine Shop	2	3 and 30 h.p.
Wagon Shop	1	30 h.p.
Carpenter Shop	4	3 to 15 h.p.
Power House No. 2 and Boiler Room	10	2 to 75 h.p.
Water Cooling Tower, Ice Plant, etc.	8	2 to 90 h.p.
Keg Washing Houses	14	2 to 30 h.p.
Dry Grain Dept.	3	15, 20, & 25 h.p.
Hop Storage House	1	10 h.p.
Pump House	9	1 to 120 h.p.
Water Filter Station	3	7 and 50 h.p.
Lime House	3	1 and 5 h.p.
Glass Works	15	1/2 to 60 h.p.
Stables	4	1 to 25 h.p.
Main Office	1	10 h.p.
Automobile Garage	4	3 to 10 h.p.

TABLE II

LOCATION		No. Motors	Description of Motor	Machine operated, or other work performed
Building	Floor			
Barley Cleaning House	1	1	27 h.p. 400 r.p.m shunt	Horizontal grain elevator
	1	1	27 1/2 h.p. 400 r.p.m. shunt	Shaft for emptying cars
	2	1	10 h.p. 330 r.p.m. shunt	Horizontal grain elevator
	3	2	15 h.p. 500 r.p.m. shunt	Barley separators.
	4 and 5	2 each	30 h.p. 500 r.p.m. shunt	Barley cleaning and separating machs.
	6	2	27 1/2 h.p. 400 r.p.m. shunt	Vertical grain elevators
	6	6	8 h.p. 330 r.p.m. shunt	Horizontal barley conveyors
	6	2	15 h.p. 330 r.p.m. shunt	Horizontal barley conveyors
	7	1	27 1/2 h.p. 425 r.p.m. shunt	Vertical grain elevator
	7	2	15 h.p. 300 r.p.m. shunt	Grain conveyor over bridge
	7	4	10 h.p. 330 r.p.m. shunt	Elevators and conveyors
	8	2	15 h.p. 550 r.p.m. shunt	Grain elevators—bottom to top floor
	8	3	10 h.p. 330 r.p.m. shunt	Grain conveyor
	8	1	10 h.p. series	Elevator
Malt House	6	1	50 h.p. 515 r.p.m. shunt	Main grain malt elevator leg
	5	2	25 h.p. 410 r.p.m. shunt	Malt conveyors
	3 and 4	1 each	25 h.p. 410 r.p.m. shunt	Malt stirring machines
	2	2	10 h.p. slow speed shunt	Malt conveyors
		1	25 h.p. 410 r.p.m. shunt	Dry malt conveyor
		4	35 h.p. 610 r.p.m. shunt	Ventilating fan
		2	15 h.p.	Freight and passenger elevators
Brew House	6	2	15 h.p. 560 r.p.m. shunt	Malt conveyors and elevators
	6	1	25 h.p. series	Passenger elevator
	5	1	25 h.p. variable speed comp.	Malt mill
	4	1	50 h.p. 550 r.p.m. shunt	4 malt mills & 4 rice mills
	3	1	20 h.p. variable speed shunt	1 mesh tub
	3	1	30 h.p. variable speed shunt	1 mesh tub
	3	1	65 h.p. 540 r.p.m. shunt	4 mesh tubs
	2	1	40 h.p. 450 r.p.m. shunt	1 mesh tub
	2	1	50 h.p. 500 r.p.m. shunt	4 mesh tubs
	2	1	7 1/2 h.p. 1100 r.p.m. shunt	Centrifugal pump for washing mesh tubs
	2	1	25 h.p. 975 r.p.m. shunt	Rotary pump for pumping wet malt
	1	1	35 h.p. 450 r.p.m. shunt	4 centrifugal beer pumps
	1	1	20 h.p. shunt	Centrifugal beer pump
	1	1	30 h.p.	Centrifugal beer pump
Old Brew House	2	1	50 h.p. 550 r.p.m. compound	4 large mesh tubs and one freight elevator
	1	1	15 h.p. slow speed shunt	Wet malt conveyor
Old Brew House Con't	1	1	20 h.p. slow speed shunt	Beer filter washing machine
Water Cooling Tower		1	25 h.p. 1000 r.p.m series	Cooling fan
		2	50 h.p. 550 r.p.m. compound	120 in. cooling fans
Power House No. 1		2	50 h.p. 900 r.p.m. shunt	Centrifugal pumps for condenser
		2	15 h.p. 550 r.p.m. series	Vacuum pumps
		3	30 h.p. 515 r.p.m. series	Cooling fans
Water Filter Plant for Beer	1	1	20 h.p. 1200 r.p.m. shunt	Centrifugal pump
	1	2	15 h.p. 1200 r.p.m. shunt	Centrifugal pumps
	1	1	25 h.p. 1100 r.p.m. compound	Centrifugal pump
Refrigerating House		2	25 h.p. 725 r.p.m. shunt	Brine pumps
		1	15 h.p. 800 r.p.m. shunt	Brine pump
		1	40 h.p. 915 r.p.m. shunt	Centrifugal pump
		1	10 h.p. high speed shunt	Pump
Stock House No. 4	1	1	10 h.p. 1050 r.p.m. shunt	Beer pump
	1	2	25 h.p. 1200 r.p.m. shunt	Centrifugal beer pump
Stock House No. 10	2	1	15 h.p. 2000 r.p.m. shunt	Centrifugal beer pump
Machine Shop		1	30 h.p. 550 r.p.m	16 machines
Carpenter Shop		1	15 h.p. 900 r.p.m.	16 machines
		1	20 h.p. 700 r.p.m.	4 machines
Power House No. 2		2	75 h.p. 670 r.p.m. compound	Centrifugal pumps
		1	150 h.p. 500 r.p.m.	Centrifugal pump
Water Cooling Tower, Ice Plant etc.		5	30 h.p. 625 r.p.m. series	Large cooling fans
		2	90 h.p. shunt	Large cooling fans
Keg Wash House No. 3		1	10 h.p. 950 r.p.m.	Air compressor
		1	15 h.p. 750 r.p.m.	Air compressor
		1	30 h.p. 550 r.p.m.	
		1	30 h.p. 550 r.p.m.	Shaft
Keg Wash House No. 4		1	10 h.p.	Bearing machine
		1	20 h.p.	Line shaft
Dry Grain Dept.		1	20 h.p. slow speed	Grain elevators
		1	25 h.p. slow speed	Line shaft
		1	15 h.p. slow speed	Sack machines
Pump House		1	120 h.p. 500 r.p.m.	Centrifugal pump
		1	40 h.p. 975 r.p.m.	Centrifugal pump
		1	50 h.p. 550 r.p.m.	Plunger pump
		1	20 h.p.	Pumps sand
Water Filter Station		1	50 h.p. slow speed	Pumps water from filter station to brewery
		1	50 h.p. 850 r.p.m.	Pumps water to brewery, also operates agitators
Glass Works		1	60 h.p.	Pressure blowers
		1	15 h.p. slow speed	Unloading freight cars
		1	50 h.p. 650 r.p.m.	Pressure blower

ELECTRIC POWER VERSUS STEAM POWER

By R. E. Barker

It need hardly be chronicled that in the last decade the use of electric power has increased amazingly, and in all branches of manufacturing industry its adoption has resulted in an improved condition from every point of view. The quality of work done has been raised, the quantity has been increased, the expense reduced, and the establishment has been made cleaner and better for the operatives. These advantages are enhanced by the use of the individual electric motor drive for the various machines which make up the factory equipment, and it will, perhaps, be of interest to show, by statistics taken from the last census reports, how greatly the use of electric motor drive, particularly of the smaller sizes, has increased within the last few years.

During this time we find that:

(1) Steam power used in Manufacturing has increased . . 136%[†]

(2) Electric power used in Manufacturing has increased . 7292%

(3) Steam power expressed as percentage of total power has declined 3%

(4) Electric power expressed as percentage of total power has increased 7.6%

These figures show clearly that the many advantages of the use of electric power are becoming more and more evident to the average manufacturer, and that the use of the electric system is expanding at a very satisfactory rate.

Year	1905	1900	1890	1880	1870
* Total horse power	14,641,544	10,409,625	5,954,655	3,410,837	2,346,142
* Average h.p. per plant . . .	108.8	78.0	59.1	39.7	9.3
No. steam engines	127,425	130,754	91,410	56,483	N.R.
H.p. steam engines	10,828,111	8,140,533	4,581,595	2,185,458	1,215,711
Per cent. of total h.p. . . .	73.9	78.2	76.9	64.1	51.8
No. electric motors	73,120	16,902	N.R.	N.R.	N.R.
H.p. electric motors	1,150,891	310,661	15,569	N.R.	N.R.
Per cent. of total h.p. . . .	7.9	3.0	0.3	......	......

* These figures include all subdivisions such as water wheels, gas engines, etc. N.R. indicates not reported.

Steam has long occupied the pre-eminent position as a source of power in manufacturing, and until about 1896 it furnished an ever increasing percentage of the total power used for such purposes. Since that date its percentage has fallen off and there has been a marked increase in the percentage of total power which has been furnished by electric motors.

The above table gives the figures of total reported horse-power used, and its division between steam and electric power translating devices. It has been considered unnecessary to take account of the other subdivisions, such as water wheels, internal combustion engines, etc., which are also used to a limited extent for like purposes.

Since the reports on electric motors were not made in detail until the year 1890, conclusions can be drawn only for the period of fifteen years thereafter.

That the average size of motors used for power purposes has changed in the space of five years is shown by the following table:

	1905	1900
No. motors . . .	79,877	35,604
H.p. motors . . .	678,910	515,705
Average h.p. per motor	8.5	14.5

The last item shows a reduction in size of 41 per cent., or a marked tendency towards the use of smaller motors. In the period mentioned the number of motors used had increased 124 per cent., and therefore the proof is conclusive that the modern tendency is in the direction of individual motor drive.

The fact that the average size of motor per horse-power used has become smaller, in the face of the enormous growing adoption of electric drives, is an indication of the recognized flexibility of electric power for emergency work or breakdown, or for overtime requirements. The small motor may be installed more readily than a larger unit and without much preliminary planning or construction. The ready 24 hour service of the central station plants avoids the necessity for large investment tied up in isolated plants so far as centrally located manufacturers are concerned.

[†] A considerable portion of this increase of steam power is caused by its extended use in driving electric generators.

Nor should it be forgotten that electricity has penetrated and opened many sections where steam could not commercially make its way.

RADIAL REFLECTORS FOR SERIES TUNGSTEN LAMPS

By T. K. P. Stilwell

Previously, in connection with series incandescent street lighting, a metal hood has been used which acted both as a weather protection to the series socket, and also as a reflector.

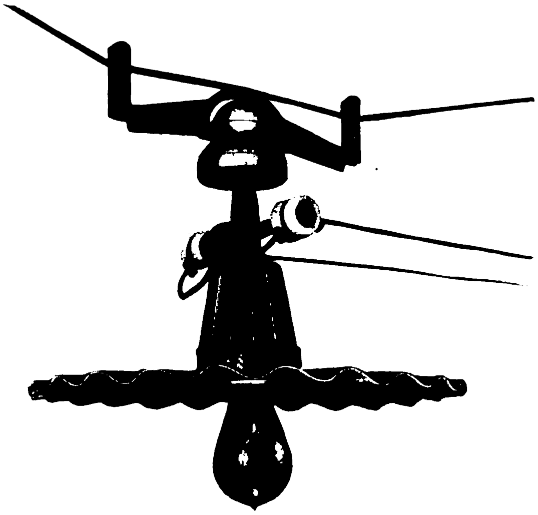


Fig. 1. Radial Reflector, Attached to Center Span Fixture for Street Lighting

The advantage it possessed was apparently on the side of the former, as its shape was such that, owing to the characteristic light distribution of the incandescent lamp, it did not direct the rays in the most useful direction. In the earlier types, this reflector was made up of a thin sheet metal covered with air-dried enamel paint. After a short time, due to natural conditions, this enamel paint would commence to peel and expose the metal to the weather, when it would soon become rusty. This peeling off of paint not only spoiled the appearance of the device, but greatly decreased its value as a reflector of light.

To supplant this reflector and avoid the difficulties just mentioned, the General Electric Company have brought out the Radial Reflector. This is made of substantial sheet metal, and has three coats of fire enamel applied on both sides, making it absolutely impervious to the attacks of weather. The porcelain reflecting surface is much more durable than paint, stays clean longer, and is more readily cleaned in event of its getting covered with dirt and dust while in use. This reflector is 20 inches in diameter, and by means of a cast iron adapter which acts as a protection for the series socket, it can be attached directly to the cross arm of the standard series incandescent goose-neck bracket, and also to the cross arm of the center span fixture, for street lighting. (Fig. 1)

Incandescent lamps for street lighting are generally placed about 12 feet above the roadway, and from 50 to 100 feet apart. It is evident that there must be sufficient illumination reaching the ground midway between lamps. In other words, to render the illumination most effective, as much light as possible should be directed at a small angle (about five to fifteen degrees) below the horizontal, without casting a shadow underneath the lamp. Practically all the light directed above the horizontal is wasted. The old type of street reflector now in common use, reflects the light which it receives in the desired direction, but allows a large portion

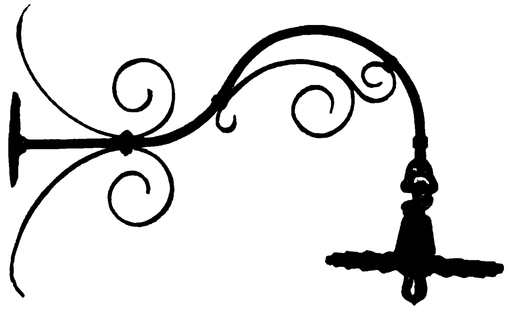


Fig. 2. Radial Reflector Fitted to Street Bracket

to escape upward. The Radial Reflector is shaped so as to receive nearly all the light emitted above the horizontal and reflect it away from the lamp. Its relative effectiveness is indicated in the accompanying photometric curve (Fig. 3). This shows an increase of 16 per cent. in the light at 10 degrees below the horizontal, and a total increase of 19.5 per cent. in the lower hemisphere over the old type of reflector; and an increase of 25 per cent. in the light at 10 degrees below the horizontal, and a total increase of 39 per cent. in the lower hemisphere over that given by the lamp without any reflector at all. Figure 2 shows the series street bracket equipped with the Radial Reflector, cast iron adapter, and bracket ornamentation.

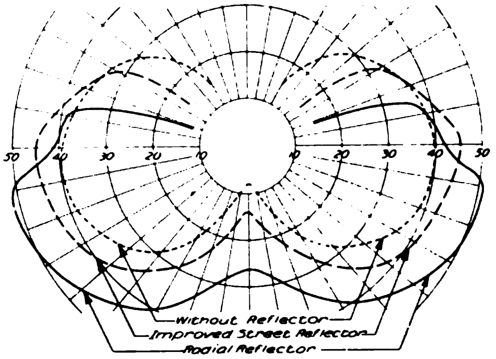


Fig. 3. Photometric Curve of Radial Reflector

It is well to remember that when Radial Reflectors are specified on requisitions, the pole plate (Catalogue No. 46240) should also be recommended in cases where this reflector is to be used in connection with the goose-neck bracket. This is found necessary owing to the fact that with the larger exposed surface, more weight is liable to come at the extreme end of the bracket, due to snow, slush, etc., accumulating on the top of this device. This accumulation, however, will only be a temporary one as the radially placed corrugations in the reflector will tend to drain off any water or moisture. It is recommended that this larger pole plate be used not only with the Radial Reflector, but with all street brackets, as it has been found that the present pole plate that is used is too small for the purpose.

NATURAL GAS AND ELECTRICITY

The apparently low rate at which natural gas is sold for illuminating purposes, has often raised the question, in the minds of those not thoroughly conversant with the situation, as to exactly what bearing its introduction might have upon the status of electric lighting properties. Nowhere has there been a more excellent opportunity for natural gas to show its superiority than in the states of Kansas and Oklahoma, where during the past ten years, its presence has been discovered in hitherto unimagined quantities.

With these facts in mind, the following letter from Mr. Schaefer, of Kansas City, is most interesting, and may serve in some measure to answer those questions which have arisen in this connection.

"For the past ten years I have been in a position to watch the development of natural gas in this territory. It is undoubtedly true that the supply of natural gas in Kansas, and even to a greater degree in Oklahoma, far exceeds to-day the supply that was ever on hand in Pennsylvania, Ohio, Indiana, or any of the older and better known fields. Natural gas sells, wholesale from the wells, at 2 and 3 cents per 1000 cubic feet to the pipe lines, which may be owned by large manufacturing companies, such as brick and tile works, cement plants, or subsidiary pipe lines distributing gas in cities.

"In plain words, natural gas is not, and never can be a serious competitor of electricity for light and power. Even where it is plentiful, the streets are lighted by electricity, and business houses as well as residences use electric light. Natural gas has its own field for cooking, heating, use in furnaces in houses, under boilers, etc. It sells usually for 25 cents per 1000 cubic feet, and for manufacturing purposes at 10 cents in the summer, and 12½ cents in the winter; in several cases, the supply is entirely cut off from manufacturing plants during the winter months, and it is used for domestic purposes only. Natural gas under boilers stands on a par with coal, when coal is $2.50 a ton, and gas of the best grade is 10 cents per 1000 cubic feet.

"The permanency of a natural gas supply is never established, and at the best can only be guessed at. If it were an assured fact for, say, twenty years, it would justify the investment called for; but it requires an extraordinary investment in comparison with the income. Inasmuch as natural gas sells at about 25 cents per 1000 cubic feet as against artificial gas at $1.00, its consumption is from ten to twenty times as much, and this requires from ten to twenty times the area of pipes to convey it. Old pipes which carried artificial gas are not suitable, for the reason that while coal gas deposits a tar product in the pipes which keeps them tight at the low pressure used, natural gas in its dry state will absorb these tar products; and as the pressure under which natural gas is forced is always much higher than that in coal gas systems, the result is heavy and constant leakage. Therefore, on account of the large quantity consumed and the defects above referred to, it is better and cheaper to lay new mains in accordance with its requirements.

"As an example, let us consider a typical balance sheet of a natural gas company in a town of 20,000 people.

Cost of new mains	$250,000.00	
Interest and depreciation at 12%		$30,000.00
Annual consumption 480,000,000 cu. ft. of gas at 25 cents per 1000 cu. ft.	120,000.00	
75 per cent. of which goes to the pipe line	90,000.00	
Gross Receipts		30,000.00

"Taking the cost of doing business: office rent, salaries of officers, labor, collections, etc., it at once becomes apparent, that instead of taking a legitimate figure of 12 per cent. for interest and depreciation, we can only allow 5 per cent. or $12,500.00 for them, leaving $17,500.00, or 7 per cent. on the investment to cover operating expenses and profits, with no chance for a sinking or contingent fund. Eventually the supply will give out, and when artificial gas has to be supplied at about $1.00, the consumption decreases and the large investment in pipe lines has to be paid.

"The electric light and power business increases with the advent of natural gas, as it is more simple and satisfactory; and where a good light and power plant exists, reasonably cheap electrical energy can be furnished. In one town of this kind current is sold at from 2 to 10 cents, according to time and character; whether in day time, at peak load, after peak load, and whether for light or power.

"One of the first considerations of an electric light and power plant should be cheap and large production, with efficient and practical distribution; one should be very careful to always give good electrical service.

"From the consumers standpoint the use of natural gas has many drawbacks.

"The heat in lighting by gas is objectionable.

"The color of light is far from desirable.

"The renewal of mantles costs more than the gas itself when used for lighting.

"A gas engine amounts to more than a motor in first cost and requires special care to maintain.

"Further it must be remembered that the numerous electrical appliances are becoming household necessities.

"Electricity is easier to control, is safer, and more flexible in every way.

"It should also be noted that gas has to be pumped every fifty miles, and such pumping requires 8 per cent. of the amount of gas to be pumped for fuel in gas engines.

"With the efficient and cheap motors and generators of to-day, the low cost of copper, and the high efficiency in translating devices now, and also the absolute success of tungsten lamps, the electric light plant has nothing to fear from natural gas competition. Both have their own useful fields, and with intelligence in investment, the electric plant should survive the gas plant, especially if cheap fuel is at hand.

"Electric light plants in this territory are not anxious to consolidate with gas plants after they have investigated. In some cases gas plant or natural gas owners desire to utilize the gas to manufacture electricity and transmit it as a commercial article.

"Should I own an electric light plant, I should welcome natural gas, as in all cases it has increased the consumption of electricity. If, on the other hand, one could own the gas wells and pipe line at a low figure, and sell gas at 25 cents it would be a good proposition. The pipe line company here gets 75 per cent. of the gross receipts."

J. F. Schaefer

NOTES ON THE MULTIPLE OPERATION OF TRANSFORMERS

By J. W. Wooldridge

Often in the multiple operation of small transformers little attention is given to their individual characteristics, it being assumed that no trouble will result provided their total kilowatt capacity is sufficient to carry the load. In a great many cases there is a natural tendency for each transformer to take its proper load.

The following notes will be of interest in showing why this is so, as well as in giving the proper method of determining the division of load among transformers connected in a common secondary net-work.

Transformers operated in multiple will divide the load inversely as their impedance, or directly as their admittance. Hence, if transformers are to operate successfully in multiple, they must have the same per cent. of impedance volts at the rated load current, and the ratio of the primary voltage to the secondary voltage must be the same.

If transformers do not have the same per cent. of impedance volts, at rated load current, the amount of load taken by each can be determined as shown in the following examples:

Assume that we have five transformers operating in multiple of the following capacities, 4 kw., 5 kw., 10 kw., 15 kw., and 50 kw.; the impedance volts at rated load current being, 2.41 per cent., 2.82 per cent., 2.59 per cent., 3.0 per cent. and 3.14 per cent. respectively.

Since the load is divided in proportion to the relative admittance of each transformer, these factors may be determined as follows:

Size of Transformer	Impedance volts	Relative admittance or carrying power = $\frac{\text{kw. Capacity}}{\text{\% Impedance Volts}}$
4	2.41%	$\frac{4}{2.41} = 1.66$
5	2.82%	$\frac{5}{2.82} = 1.77$
10	2.59%	$\frac{10}{2.59} = 3.86$
15	3.00%	$\frac{15}{3.0} = 5.00$
50	3.14%	$\frac{50}{3.14} = 15.90$
84 = kw. total		28.19 = total admittance

The load taken by each transformer will bear the same relation to total load that the admittance of that transformer bears to the total admittance, as follows:

Size trans.	% Impressed volts at full load	Relative admittance	Kilowatt load taken	Per cent. of total load	Per cent. of rated load
4	2.41	1.66	$\frac{1.66 \times 84}{28.19} = 4.95$	5.89	123.7
5	2.82	1.77	$\frac{1.77 \times 84}{28.19} = 5.28$	6.29	105.6
10	2.59	3.86	$\frac{3.86 \times 84}{28.19} = 11.49$	13.69	114.9
15	3.00	5.00	$\frac{5.00 \times 84}{28.19} = 14.90$	17.73	99.3
50	3.14	15.90	$\frac{15.90 \times 84}{28.19} = 47.38$	56.4	94.8
84 kw. total			84.00	100% kw.	

If, after the load which each transformer will carry is known, it is found that the load on some of the transformers will be too great for safe operation, a part of this load may be transferred to the other transformers by inserting a reactance coil in series with the transformers carrying too much load.

These calculations apply to transformers grouped closely together, so that the resistance of connecting cables is negligible.

In practical construction, however, it is not desirable to bank transformers connected to a distribution system, since a greater economy of copper is obtained by scattering them out so that they will feed into the distributing network at various points. This arrangement requires that the large transformers be placed near the center of distribution and the smaller ones so arranged as to feed the system at points more remote.

Assume, therefore, that a 50 kw. and a 10 kw. transformer are so distributed as to have a drop of 3 per cent. from each transformer to the center of distribution, and also assume a reactance drop of 3 per cent. in the same way. To corresponding components of each transformer we must therefore add 3 per cent.

We then have the following conditions:

	50 kw. transformer	10 kw. transformer
Resistance trans.	1.08%	1.49%
" line	3.00%	3.00%
Reactance trans.	2.95%	2.12%
" line	3.00%	3.00%
Impedance	3.14%	2.59%

$\sqrt{(1.08+3)^2+(2.95+3)^2} = 7.22$ = Impedance of 50 kw. including line.

$\sqrt{(1.49+3)^2+(2.12+3)^2} = 6.8$ = Impedance of 10 kw. including line.

The division of load under these conditions is as follows:

Size trans.	% Impedance volts at full load	Relative admittance	Kilowatt load taken	Per cent. of total load	Per cent. of rated load
10	6.8	1.47	$\frac{1.47\times 60}{8.4} = 10.5$	17.5	105.0
50	7.22	6.93	$\frac{6.93\times 60}{8.4} = 49.5$	82.5	99.0
60 kw. total				100	

The same transformers if banked close to each other with no load between them will divide the load as follows:

10	2.59	3.86	$\frac{3.86\times 60}{19.76} = 11.7$	19.5	117.0
50	3.14	15.90	$\frac{15.9\times 60}{19.76} = 48.3$	80.5	96.6
60 kw. total				100	

In a secondary network it is often difficult to determine the exact impedance or resistance of the lines from the transformers or the exact location of the center of distribution, and calculations should therefore be checked by measuring the current output of each transformer when supplying maximum load conditions. This can be conveniently and accurately done by means of a cable testing current transformer.

REGULATE STOCKS NOW*

By J. E. Perego

The men who have their fingers on the pulse of our commercial life, and whose statistics measure the beats of the great arteries of business, are advising us that conditions are improving; the pulse is quickening, and a normal tone is becoming more of a surety.

This is as it should be. We have had time to adjust business to a great degree to the conditions brought upon us by the calamities of a few months ago. Manufacturers have curtailed their orders for raw material, and also their output, and have used up surplus stocks they had on hand. Wholesalers and jobbers have likewise reduced their stocks to the minimum, and so down the line from mine to finished product, from raw material to consumer, the closest scrutiny has been exercised to prevent congestion and loss.

Manufacturers, dealers and consumers of electrical machinery and supplies were among the first to be affected by the tidal wave of disaster, and they have made strenuous efforts to adjust themselves to the new conditions imposed.

Now that a more healthy tone is evident, it is the part of wisdom for the electrical manufacturer and dealer to foresee the conditions and meet them as they appear. Unless this is done, there will be greater difficulty than has been heretofore experienced in meeting the demands of consumers.

We have climbed the hill of prosperity and know how inadequate has been the ability of our jobbers, wholesalers and manufacturers to supply promptly the contractor, the central station and the public with the material they required; and when such material was obtainable, such was the congestion on the lines of transportation that long delays were the rule.

Now is the time when every dealer of apparatus and supplies should look over his stock and figure his probable requirements; and then order all he can safely handle. This will assist the manufacturer in his estimates of what he is likely to require in the matter of raw material and skilled labor in order to produce the finished product. Every item that can be safely ordered now will assist just that much in overcoming the difficulties that are sure to come on us both in production and transportation if orders are held up until material must be used. Prices now are right, and advantage should be taken of them and of the general conditions. To do this is to "take time by the forelock."

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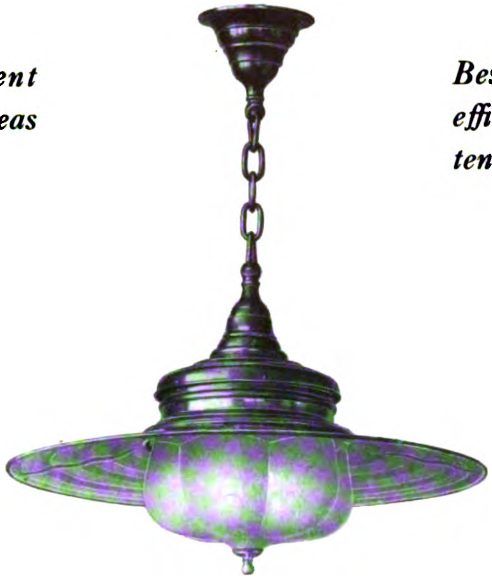

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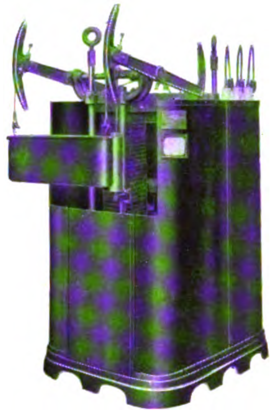

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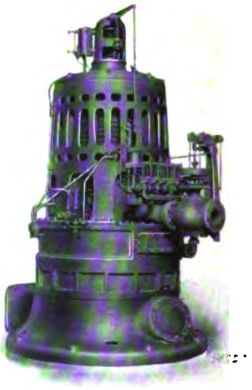

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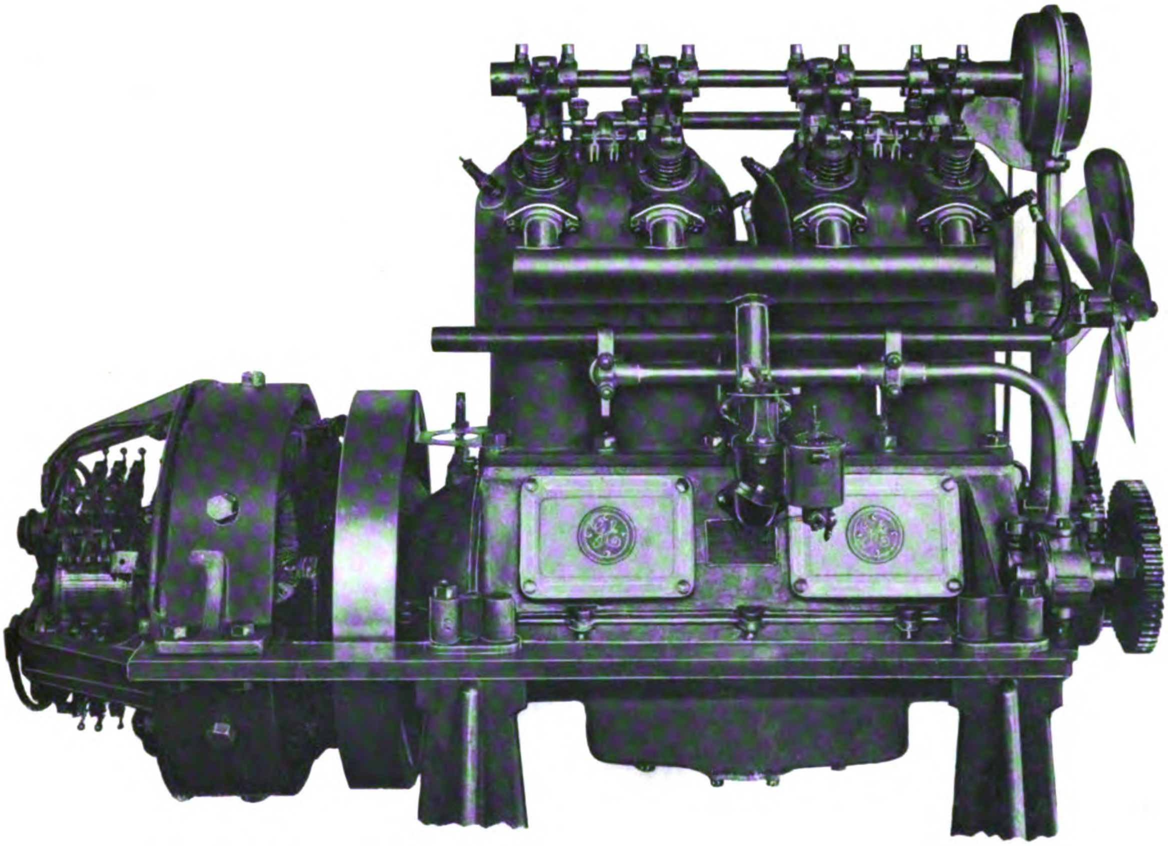

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(See Page 214)

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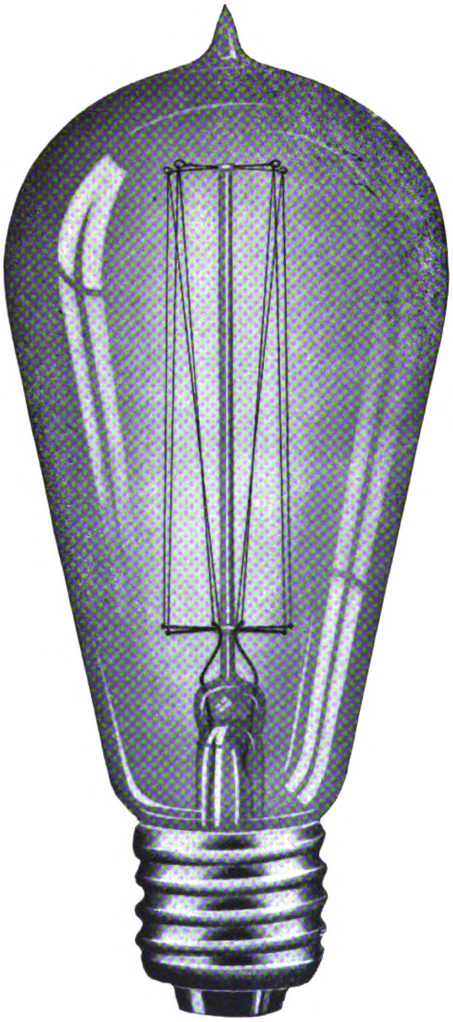

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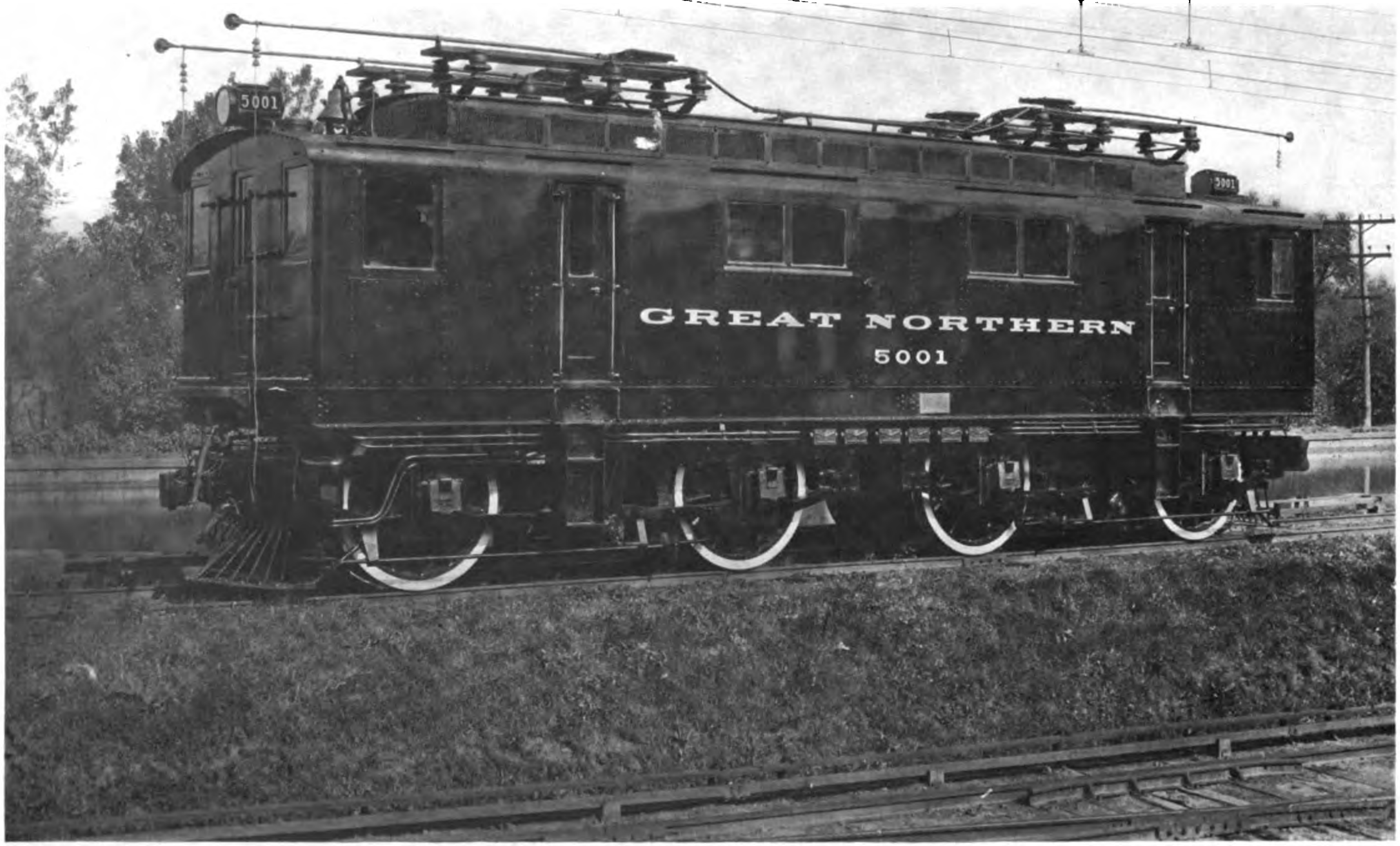

113 Ton Locomotive, Equipped with Four 400 h.p. Three Phase Induction Motors

(See page 224)

GENERAL ELECTRIC
REVIEW

SPRAGUE-GENERAL ELECTRIC AUTOMATIC CONTROL*

BY F. E. CASE
ENGINEER OF RAILWAY EQUIPMENT, GENERAL ELECTRIC COMPANY

When Mr. F. J. Sprague first suggested the use of several motor cars in a train, all controlled by means of pilot wires from the head car, he urged the adoption of automatic acceleration; that is, means for maintaining a definite amount of current input to the motors. In the first commercial installation of multiple unit control, on the South Side Elevated Railway of Chicago, each car was provided with a current limit relay for automatically governing the motor current, independently of the other cars in the train.

As the cylinder controller was at that time the type in general use on street railways, this first installation naturally used it, but instead of being operated by hand· a small motor attached through gearing to the controller cylinder turned it on and off as desired. By means of relays and a secondary system of wiring extending the length of the train to the master controller at the front end, simultaneous operation of the various pilot motors driving the controllers was secured. The South Side Elevated cars were each equipped with two 50 h.p. motors, and in consequence the pilot motor attachment to the cylinder controller made a fairly satisfactory combination. The subsequent increase in size and number of motors generally used per equipment, however, made it necessary to develop an entirely different type of motor controller to meet the exacting conditions of multiple unit operation.

The form in universal use, both in this country and abroad, comprises separately actuated switch units, or contactors, each one having the function of a controller finger and its accompanying cylinder segment. The contactor manufactured by the General Electric Company, one size of which is shown in Fig. 1, is directly operated by an electromagnet which derives a small amount of line current through the master controller shown in Fig. 2.

The contactor type of controller has many advantages over the cylinder form, including the ability to provide a powerful individual magnetic blow-out for promptly extinguishing each arc, the isolation of the contacts, and the rapidity of making and breaking the circuit. As each contactor is a complete element, it has the further advantage of great flexibility in arrangement and grouping for obtaining various motor and resistance combinations to suit different conditions of operation and capacities of equipment.

Type M, or contactor control manufactured by the General Electric Company, has already been made for use with motors ranging from only a few horse-power to the enormous size of 6,000 h.p. used in steel rolling mills. The use of this control has made it possible to easily operate these gigantic motors where the cylinder form of controller would have been prohibitive, both on account of space occupied and difficulty of operation.

For railway service the contactors may be grouped in a single box as shown in Fig. 3, and located below the car floor, or if on a locomotive, disposed about the cab in convenient places without using valuable space. When new conditions arise which require special circuit connections, there is little difficulty in arranging the contactors to suit.

In all but the latest K type drum controllers the transition from the series to parallel connection of motors is accomplishe by quickly inserting a portion of the ori starting resistance in series with t

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* Paper presented at Convention of American Street Railway Association, Atlantic City, Oct. 12-16, 1908.

motors and then shunting one of the latter. This shunted motor is then open circuited and connected in parallel with the other motor and in series with the resistance, which is afterward cut out in several steps.

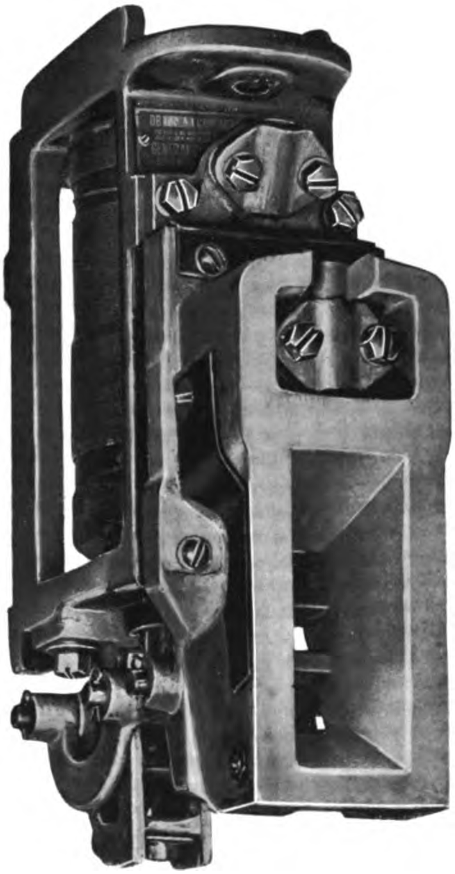


Fig. 1. General Electric Contactor

One of the important improvements in the operation of railway motors, first put into general use with contactor control a few years after its adoption, was the "bridge" method of motor and resistance connections for making the transfer from series to parallel. A set of resistances for each motor circuit is required for the purpose of making this transfer, and these resistances are connected along with the motors, first in series and then in parallel. The "bridge" connections permit a continuous torque being exerted by the motors throughout the range of steps, there being no cessation of tractive effort in passing from series to parallel as in some of the earlier types of contactor control. The exact method of accomplishing this will be described later and illustrated by a diagram.

Many of the type M, or contactor control equipments furnished by the General Electric Company are of the hand or non-automatic type, in which the master controller is provided with definite points, the same as an ordinary street car controller; and the motorman notches up step by step in a similar manner. This form of control is the simplest in circuit connections due to the absence of automatic parts. At the present time there are approximately 5500 Sprague General Electric Type M control equipments in operation in this country and other parts of the world, of which number approximately 30 per cent. are of the automatic type, in which the current input to the motors is governed by a limit relay.

The automatic form of control has been found desirable by different railways for the following reasons:

First, to prevent the abuse of the motors and equipment due to too rapid controller "feeding."

Second, to obtain an efficient and uniform acceleration.

Third, to insure the maximum comfort to passengers during this period.

It takes out of the hands of an indifferent motorman the ability to make a very jerky and disagreeable acceleration, and he can concentrate his attention to the track ahead.

Last year, in the report of the Committee on Electrical Equipment, 42.6 per cent. of motor commutator and brush holder troubles were attributed to fast feeding of controllers. It was recommended that automatic devices be used for limiting to a fixed maximum the amount of current the motors might receive. There appears to be no doubt about the injurious effects on motors when they are compelled to take an excessive amount of current during acceleration. In motors not provided with commutating poles, not only do the commutator and brushes suffer, but also the gears and pinions, as a destructive hammer blow is imparted to them. Some roads have put time limiting devices on K type controllers for accomplishing the result in a different manner, depending entirely on delaying the movement of the controller cylinder, but this does not entirely accomplish the desired results.

The rate of acceleration of an ordinary street car may be anything up to the slipping point of the wheels. With the best condition of track, and when the total weight is on the driving wheels, a rate of three miles per hour per second may be reached for a brief period, but this is not comfortable to passengers if produced suddenly. In most instances where automatic control is used, the maximum acceleration is about one and a half miles per hour per second under normal conditions. It is obviously necessary to set the current limit so that under the varied conditions of load, grade, and track adhesion, an average acceleration will be secured which relieves the motors of excessive strains and yet produces a satisfactory acceleration.

However, under some conditions it is impossible to set the current limit relay of the plain automatic control to take care of all the variables. For example, if the limit relay is set for an amount of current which will give the car the desired rate of acceleration when empty, on a level track, this amount may not be sufficient to start the car when heavily loaded, on a sharp curve or steep hill.

To overcome this obstacle several means have been employed. One is a switch for shunting the current limit relay and compelling the control to take additional steps irrespective of the current. A second method is to use two current relays having different settings. With this latter arrangement, either a master controller provided with extra positions, in which the current limit of higher setting will be cut into circuit, or a separate switch for accomplishing the same result can be used.

With either of the latter two schemes the car or train will be normally accelerated with the relay having the low current setting; but with a heavy load on a curve or grade, where conditions required it, the second relay can be cut in.

As another means for overcoming the objection to a single current setting, equipments have been furnished with current limit relays provided with dashpots for producing a definite time lag (Fig. 4). The principle of operation is that the car will accelerate, or cut out all of the resistance, in a certain minimum time under average conditions, the current setting of the relay being placed at a higher amount than will be reached during this normal acceleration. If the car is heavily loaded, or other conditions require the motors to take a much heavier current to accelerate the car, the current limit relay will come into action and prevent an abnormal amount of current being taken.

In Fig. 5 is shown a typical current record of a lightly loaded car, equipped with four 75 h.p. motors, starting on a level track. The current obtained on each step in this case was below the setting of the current limit relay and the notches were secured by a slight time element in the dashpot of the relay.

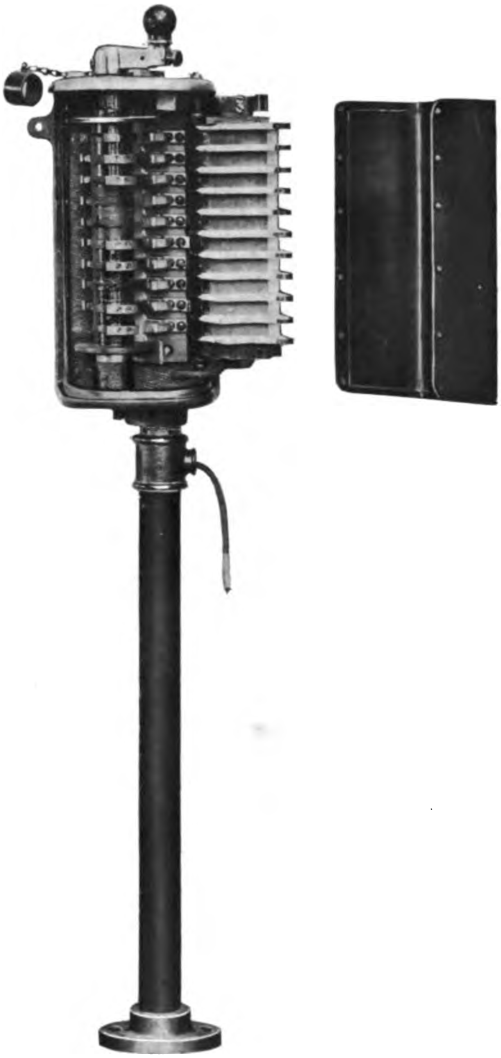


Fig. 2. Master Controller

In Fig. 6 is shown a current record of the same car loaded while accelerating on a grade. In this instance the current limit relay came into action and prevented the maximum current from exceeding a safe amount for the motors.

As this is a four motor equipment there are two groups of motors, the motors in each being connected permanently in parallel, each group being treated as a single motor in making the series-parallel connections. The current recorded is the amount taken by one pair of motors.

Nine points are shown, on the first five the motors being in series, and on the last four, in parallel. The switching point in series does not appear, this point being passed over quickly when operating automatically.

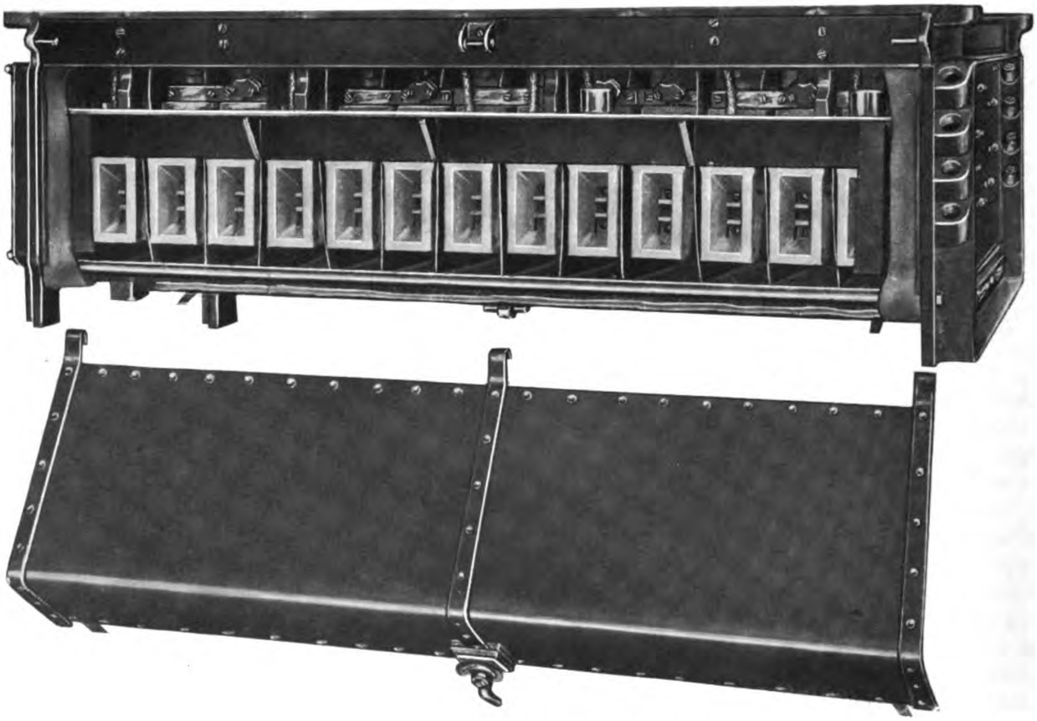


Fig. 3. Contactor Box, Showing Contactors in Place

It will be seen that practically a uniform current is maintained on the motors throughout the range of acceleration, and that in passing from series to parallel, full torque is exerted.

The question of accelerating with definite maximum current is one requiring considerable thought, as it can be readily seen that, if the torque required of the motor should vary over a wide range with the different conditions of service, there must be some method of compensating for the fixed current value of the limit relay. Otherwise the wheels will slip or the acceleration be too violent under conditions of lightest load and the motors will not be able to start the car with heavy load on a grade.

I will now show how the various motor and resistance connections are obtained with the automatic type of control.

In Fig. 8 are shown the motor and resistance circuits in a simplified diagrammatic form of a representative series parallel contactor control giving the "bridge" connections. In the key below the diagram, the various connections effected by the contactors may be easily traced out. The crosses in the diagram represent the location of contactors and the letters and numerals identify them.

The cap plate of the master controller is provided with two series and two parallel points. When turning to the first point the reverser is thrown for the corresponding direction of car movement, if it has not previously been moved to it, and contactors L-1, L-2 and S are energized for giving the series connection of motors with all resistance in circuit. Interlocks prevent the motors taking current unless the reverser is in the correct position.

On the second point of the master controller the resistance is cut out in several steps. R-4 contactor is first closed, cutting out the three sections of resistance adjacent to No. 2 motor. On the succeeding series steps, the sections of resistance adjacent to No. 1 motor are cut out separately. This arrangement of resistance steps permits maintaining a very uniform maximum current in passing from step to step. After the last series position has been reached, all of the resistance being short circuited, the "bridge" contactor "B" is next closed, and automatically the series contactor "S", and the resistance contactors are opened.

On the third point of the master controller contactors, M-1 and M-2 are closed, connecting the motors in parallel, the resistance for No. 1 motor being connected to ground by M-1 contactor, and the resistance for No. 2 motor being connected to trolley by M-2 contactor. With properly balanced resistances, the "bridge" connection acts merely as a balance for the difference in current of the two motors, and practically no current passes through it.

The "bridge" contactor, having completed its function of transferring the motors from series to parallel is opened as soon as the transfer is made. This transition is effected automatically, with no interruption in the sequence, and interlock contacts on the contactors prevent any change in the order being produced accidently. It will be seen from the diagram that, should contactors M-1, S and M-2 be closed simultaneously, a short circuit from trolley to ground would occur through them; but the automatic interlocking prevents the three switches from being closed at the same time and no incorrect operation can occur.

On the fourth point of the master controller the resistance is again cut out in several steps. In operation, the controller handle may be turned to fourth point immediately and the contactors will close in the proper order for first producing series and then parallel connections of motors.

It will be noted that the diagram and key show six steps in series and four in parallel, but the first step in series is of high resistance and intended merely for slow car movement required in switching and coupling, and the current is of such low value that the current limit relay will not operate.

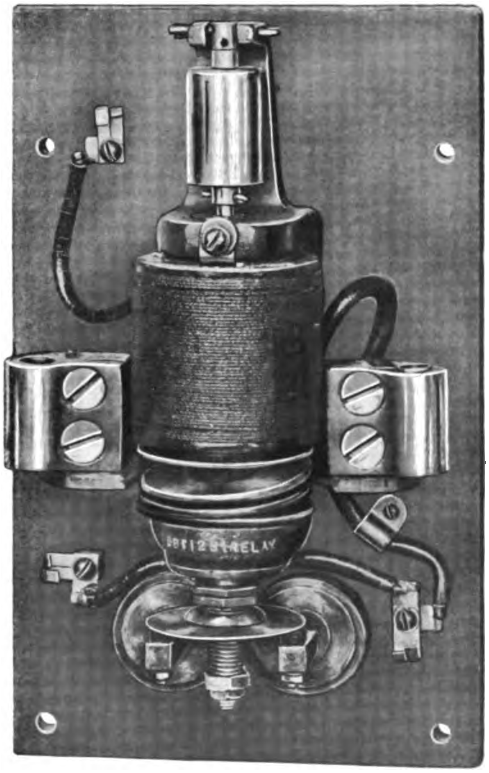


Fig. 4. Current Limiting Relay

In the automatic form of contactor control the master controller directly operates, through train wires, the electrically operated reverser and such contactors as are required for producing the series and parallel connections. The master controller also operates directly the first resistance contactor, but the contactors for the succeeding steps are actuated indirectly by the master controller through the current limit relay and under its direct control. One motor circuit passes through a series coil on this relay and when the desired maximum current has been reached, the relay contacts will be held in their upper position, thereby opening the resistance contactor circuit and preventing further progression.

The general scheme of operation is that as each resistance contactor closes, it transfers its operating coil from a lifting to a holding circuit and also connects in the operating coil of the contactor for the succeeding step. At the same time the resistance contactor is closed, the current limit relay, which is provided with a lifting coil in the contactor circuit, raises and interrupts the lifting circuit to prevent further progression of the contactors until it again drops. If the motor current flowing through the series coil is sufficiently high, the relay will not immediately drop, and in this manner the automatic current limiting feature is secured.

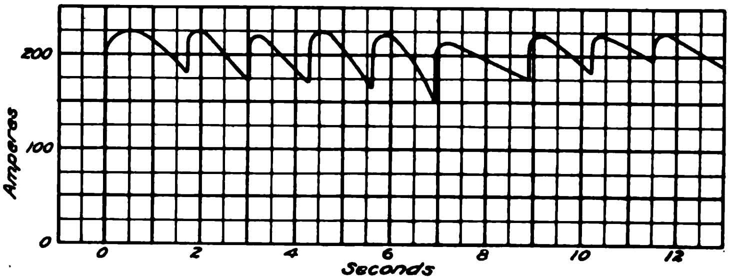


Fig. 5. Current Record of Lightly Loaded Car Starting on Level Track

Fig. 7 shows the control circuit connections from the master controller to the contactors and interlocks in a simple diagrammatic manner. With the master controller on first notch, forward, current flows from T through wire 4 to reverser coil, through 5A to ground G. This throws the reverser to the proper position, if it has not been left there by previous operation. The reverser in throwing over connects wire 4 by 5B through coils L1 and L2 to ground. Current also flows through wires 2A, 2B and 2C to coil S and wires 2D, 2E, 2F, 2G and 2H to ground. The small double circles in the circuit represent resistances which have an approximate value equal to that of the contactor coil.

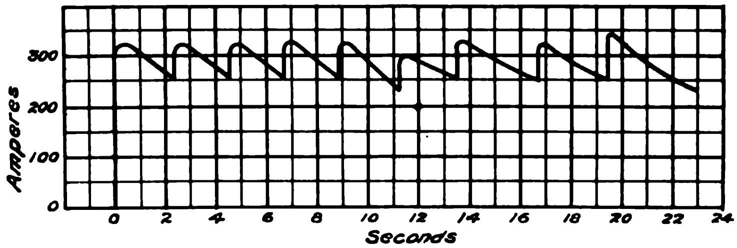


Fig. 6. Current Record of Same Car when Loaded and Accelerating on Grade

These circuits operate the necessary contactors for connecting the motors in series with all the starting resistance in. The line relay is closed, as it is connected across the motors.

When the master controller is moved to the second position, the control current flows through wire 1, current limit relay, wires 1A, 1B, 1C, coil R, R4 to 2E, etc., to ground. The RR-4 contactor and relay close simultaneously. As the contactor closes, the contact between 2K and 1C wires is made previous to the contact between 2D and 2E being broken, and also just before the relay contact is opened. The circuit through coil S then passes from wire 2D through 2J, 2K, 1C, coil RR-4, 2E, etc. to ground. The motor current flowing through the heavy coil of the relay, being increased by closing RR-4, is sufficient to hold the relay plunger, just lifted by No. 1 wire circuit, and keep its contacts open. After the motor current has dropped a predetermined amount, due to increase of motor speed, the relay plunger drops and the control circuit contacts are again closed. Current then flows through wires 1A, 1B, 1D, 1E, coil R-1, 2F, etc. to ground. This closes R-1 contactor, and its interlocks shift the coil into the circuit from 2E, placing it in series with S and RR-4, and the relay repeats its previous performance.

On the next two steps the R-2, RR-2, R-3, and RR-3 coils are energized in the same manner. When R-4 contactor closes on the last step, the control current flows through wires 1B, 1D, 1L, 1M, coil B to G. The 2C wire is opened when contactor B closes, and contactor S and the resistance contactors are permitted to open. The "bridge" contactor B is kept closed by the current passing through the 2B and 1M wires.

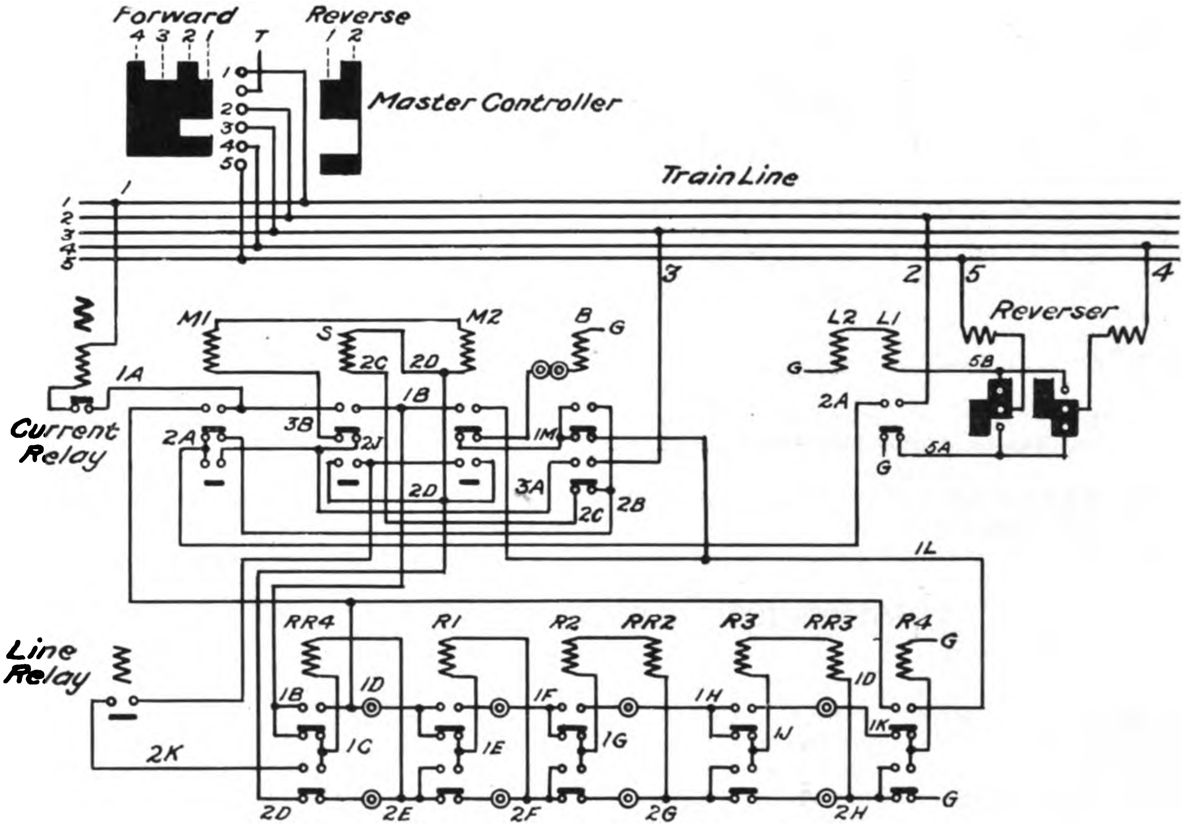
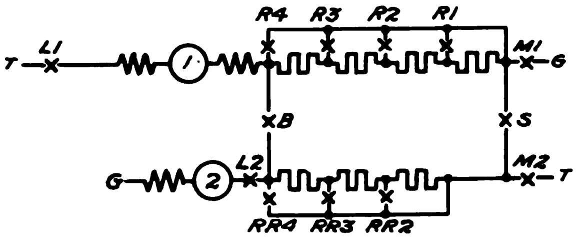


Fig. 7. Connections of Control Circuit

In the third position of the master controller an additional circuit is made through wires 3, 3A, 3B, coils M-1 and M-2, wires 2B, 2E, etc. to ground. When closing, M-2 contactor opens the circuit of the "bridge" contactor B, and M-1 contactor closes the circuit from 2A to 3B, thereby keeping M-1 and M-2 contactors closed. The motors are now connected in parallel with full resistance in circuit.

On the fourth point of the master controller, current flows through wire 1 and the current relay, and the resistance contactors are operated in the same manner as in series, but not in the same order. Current flows through 1A, 1D and 1E, coil R-1, wire 2F, etc. to G, thereby operating R-1 contactor first in parallel. After R-1 contactor has operated, R-2, RR-2, R-3, RR-3 and R-4 are closed in the order given. After R-4 contactor has closed, the current passes from 1D wire through 1L, 1B and 1C, coil RR-4, 2E, 1E, coil R-1, etc. to ground and RR-4 contactor is, therefore, the last one to close.

When it is desired to notch up slower than the normal rate the master controller handle is brought to the first point and the car slowly started. To secure a slight increase in speed the handle is turned to the second point and returned quickly to the first. This operation will lift the current limit relay and the contactor for the second step but, as it cuts off the lifting circuit, no more contactors will be closed until the movement is repeated. This method of operation can be followed until all resistance contactors are closed and full series is reached.



Steps		Contactors Closed
Switching	1	L1-L2-S
Series	2	---------RR4
	3	---------------R1
	4	-----------------R2
	5	-------------------R3
	6	---------------------R4
Bridge	6½	L1-B-L2
Parallel	7	L1-M1-M2-L2-R1
	8	------------------R2-RR2
	9	--------------------------R3-RR3
	10	------------------------------R4-RR4

Fig. 8. Motor and Resistance Circuits, Series Parallel System, with "Bridge" Connections

If desired to cut out the resistance slowly in parallel also, the controller handle is then brought to the third point and the motors will be connected in parallel with all resistance in. By turning to the fourth point and back quickly to the third, a similar operation to that in series will result.

TRANSMISSION OF ELECTRIC POWER

By E. B. Merriam

Among the more important factors that have made possible the exceedingly rapid development of this country, none has been more instrumental than that of transportation. This was the determining consideration that caused the location of our earlier cities upon navigable water, while to-day the transportation facilities afforded by the railroads are of paramount importance to the progress and development, both of our individual city and the country at large To render these facilities as efficient as possible, the rolling stock and tracks have been continually improved, and enormous sums are annually expended upon signaling devices, track walkers, and other safety expedients, without which the present speeds would be impracticable.

As the railroad is the means of transporting material products from the source of supply to the place of demand—from the farm or factory to the cities—so the transmission line is the vehicle by which the no less important but intangible product of the electric generator is carried from the place of generation to the place of utilization.

The successful operation of the former means of transportation rests upon the proper construction and maintenance of its rolling stock and track; while the continuous operation and efficiency of the latter is dependent upon the construction of its transmission line, and above all else upon the insulators. But, whereas, a vast amount of time, labor and money have been spent to add to the efficiency of the railroad by increasing the factor of safety, too little attention has been given to this feature in the case of the transmission line.

The generators, transformers, oil switching apparatus and lightning arresters have now reached a state of development such that it is possible to predict the operation of any of these in combination with each other, thus making the generation and control of the electric current a definite problem. The transmission of the current, however, is in no wise so definite a matter, as variable factors arise which materially affect the results. The distance to which this power can be transmitted is limited by the characteristics of the transmission line. At present the insulation to ground is one of the limiting features, and the steel tower construction which brings the ground nearer the wire, increases the difficulty of the problem. Switching strains and atmospheric disturbances, all classified as lightning, are other important elements of the problem that must be taken into account; and as the effect of these factors is almost impossible of pre-determination, a high factor of safety, both electrical and mechanical, is of the utmost importance. To secure this, it is almost an absolute necessity that the method of insulating and supporting the line be improved.

The natural step to take in making a better insulator would be to make the present design larger, but this is found to be awkward on account of the present great size (See Fig. 1).

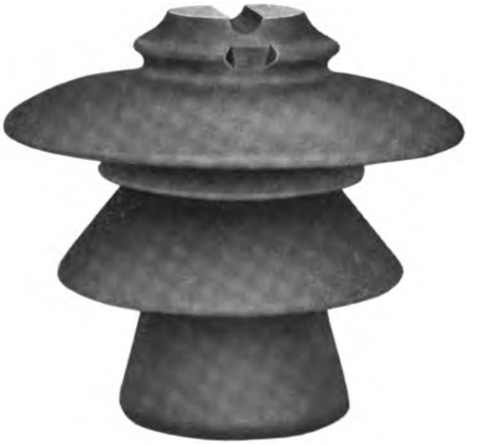


Fig. 1. Four Part Pin Insulator for 60000 Volts

To avoid this, a great many schemes have been proposed, such, for example, as supporting the wire by a treated cord or rod that has been weather-proofed in one of various ways. Some advocate the supporting of the line by double treated wooden rods, or by porcelain tripods. It has even been suggested that the pin insulator, with its cemented sections, be provided with a cast cap cemented to the insulator, forming in this way a suspension insulator from which to suspend the line. All of these schemes have their various objections, which prevent their general use, and it was only after a great deal of experimenting and investigation that a suitable form of insulator was found to meet all the conditions. This device is shown in Fig. 2.

These insulators are made of the highest grade of wet process porcelain and insure the greatest factor of safety, both electrical and mechanical. A single unit, 10 inches in diameter, will stand 85,000 volts potential test, and a number in series will increase the insulation in proportion.

The distribution of voltage across a series of insulators is of vital importance when considering the insulation afforded by a number arranged in this way. It is well known that the distribution of potential across the several petticoats of a pin insulator is uneven, and is, perhaps, more serious in this case than in the case of a series of strain insulators. The potential distribution on a *pin*, or *petticoat* insulator, made of three shells cemented together was found by actual test to be as follows:

35 per cent. across the outside shell,
21 per cent. across the intermediate shell,
44 per cent. across the inside shell.

Test being conducted at 80,000 volts, with pin grounded. With another insulator of the same design but having four petticoats, the following distribution was found, *viz:*

32 per cent. across the outside shell.
19 per cent. across the second shell,
19 per cent. across the third shell,
30 per cent. across the inner shell.

Comparing a series of *suspension* insulators with these results we find that the potential distribution for three insulators is as follows:

36 per cent. across the first insulator,
33 per cent. across the second insulator,
31 per cent. across the third insulator.

While four insulators at 100,000 volts give the following:

29 per cent. across the first insulator,
26 per cent. across the second insulator,
24 per cent. across the third insulator,
21 per cent. across the fourth insulator.

The uneven distribution across a number of suspension insulators in series is equalized near the flash over point.

Since, as shown by these tests, the highest potential is near the line, it has been suggested that a stronger insulator be installed at this point. Should such a one be installed, however, it would take still more strain.

The one thus located must not be too thick, as this would mean reduced capacity, and large capacity is demanded at this point, in order to permit the charging of the other insulators, as otherwise, the insulator in question would take more than its proportional percentage. In the insulators shown in Figs. 2 and 3, these points have been considered, and tests show them to be efficient forms of insulators, at the same time possessing no complications of design.

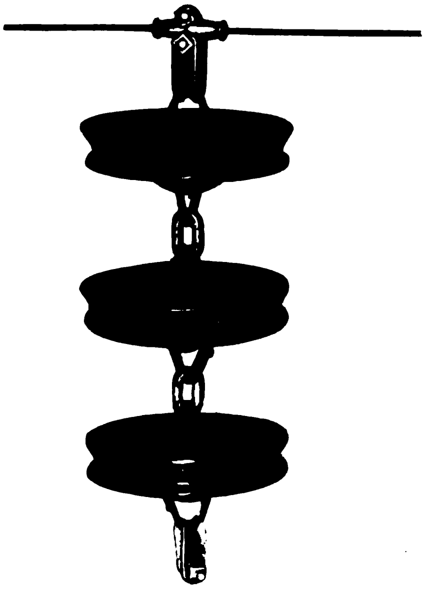


Fig. 2. Suspension Insulators

It is possible to design a suspension insulator with a number of shells, but we then have a condition where one shell may be punctured, which would result in the next shell taking the total strain, and puncturing in turn. But by providing a single unit of high insulating value, other conditions being observed, a much more efficient form of insulator is obtained.

Various tests have been made from time to time to determine the amount of voltage across the several petticoats of a pin insulator and various suspension insulators, and results made by different people vary a great deal. The spark gap method at first seems attractive, but actual tests show that this method is very misleading and that the values obtained are not a true representation of actual conditions. With the spark gap, it is possible to reach a point where one gap will charge into the next, and that into a third, and so on. That is, the presence of the spark gap equalizes the potential; so that by manipulating the conditions, we can have either an equal or unequal distribution across a series of units.

As another instance: in testing a triple petticoat insulator, it is possible to puncture the inner shell by first wetting the first and third shells, thus causing the middle shell to take practically all the voltage. This shows us how complicated this matter may become, and why different engineers can obtain different results, simply by the surface of the insulator being oily and shedding water for a time.

The shunt resistance method seems to be accurate, and the readings that have been given above were made by this method and re-checked. When making tests by this method it is necessary to permit an actual current to flow, so that the potential drop across the insulator can be measured.

The size of the testing transformer should also be considered; as it is possible with a small transformer to test an insulator under rain and have it appear to be satisfactory when this is not the case. This is because the current delivered by the transformer is so small that the film of water will carry it without steaming, assuming voltage to be held on low tension side, whereas a larger transformer would cause arcing. Results are sometimes misleading unless we consider the different transformers. In tests a point is reached where the static sparks begin to strike over the surface and being of an oscillatory nature they set up disturbances which give rise to voltages higher than that which is read on the low tension side of the transformer. In consequence of this, the insulator appears to be sparking over at a much lower voltage than is really being impressed. Some tests show this effect to a marked degree, and in a laboratory test this would indicate that the insulation was of a lower value than would show up under the actual working conditions. In view of the many sources of error that may arise in the testing of insulators, it is of first importance that this work be entrusted only to those who thoroughly understand it; who are not likely to be led astray by secondary phenomena, and who are supplied with suitable apparatus.

The porcelain used in the manufacture of insulators should be selected with the greatest care, as it must have a high insulating value and a thoroughly vitrified structure which resists the entrance of moisture; besides being free from any tendency to weaken or deteriorate in any way with age or severe service conditions.

Commercial tests on insulators, as a check on the product and manufacture, are quite essential, and should be gone into very carefully. It is a comparatively simple matter to make a dry test, but when rain tests are considered, we have to deal with a vague quantity. When some manufacturers speak of the "rain test" value of an insulator they mean that this insulator has a certain insulating value in a rain storm, the rain being supplied as the fancy of the engineer may dictate, some specifying a "cloud burst." Even though we agree on a certain precipitation, the results may vary, as the distribution of the rain in one test may be quite different from that in another, owing to the different pressure, position of nozzles, velocity of wind, condition of insulator, and the specific resistance of the water change, due to the presence of impurities. When testing suspension insulators for a rain test, the rain should be angular and the insulators vertical. It has been proposed as a more convenient method to test insulators at an angle and let the rain drop vertically. This is not satisfactory, as it is not as severe as the old method, because when the insulators are vertical they are "bridged" by the rain running off the edges.

The dew test can be controlled with some degree of precision, but is rather difficult to make owing to the complications. A steam test has been proposed which consists essentially of training a jet of steam on the insulator, or housing the insulator in a steam pot and subjecting it to the electrical test. This gives uniform results, as the evaporated water is of the same resistance and is distributed evenly.

Insulators and metal fittings operating at high voltages on transmission lines are sometimes coated with a formation, probably due to ozone, which has the appearance of an oxide. By actual test a number of insulators operating at 100,000 volts in a cloud of steam have given no trace of nitric acid unless the voltage was increased to a point where there were disruptive discharges. From this it would seem that nitric acid is only produced when there is a disruptive discharge, and is not due to corona or glowing.

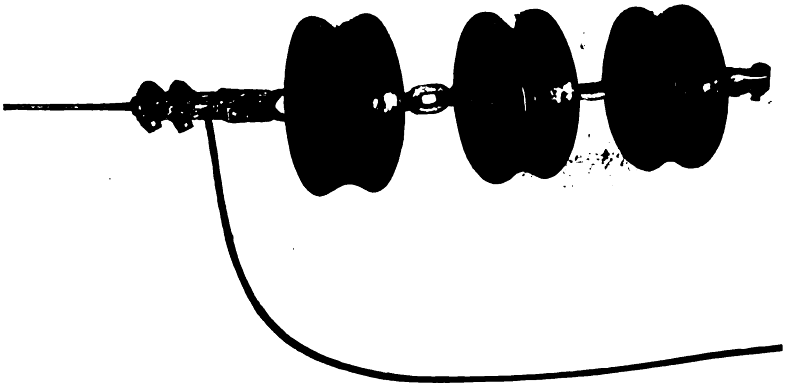


Fig. 3. Strain Insulators

There has been some discussion as to the heating of porcelain due to dielectric hysterisis. Tests have demonstrated that there are very small internal losses in the body of the insulator if the porcelain is thoroughly vitrified. If the porcelain is coarse, however, it will absorb moisture, which under electric stress will give a rise in temperature (perhaps $I_2 R$ loss) that is misleading. At the same time a poor porcelain will absorb moisture gradually giving the effect of deterioration. Three-quarters of an inch of porcelain will stand 85,000 volts commercially. Samples of porcelain taken from five different manufacturers show different percentages of absorption when the various samples were selected at different times. This indicates that even though extra precautions are taken to secure the best porcelain, there are times when porcelain that will absorb moisture is obtained in spite of specifications. From this it is easy to see that we should specify absorption tests on insulators from time to time, or even from every kiln, to be sure that the product is running uniform. "Pilot" insulators should be without glaze so as to obtain the most severe conditions; for it is possible with a good glaze to exclude moisture until that time has arrived when the glaze has become "crazed" or cracked. For this reason porcelain insulators should never rely for their insulation on the glaze; the whole body should be thoroughly vitrified. Good porcelain will stand soaking in water, and even a very small per cent of absorption should be considered enough to condemn the insulator.

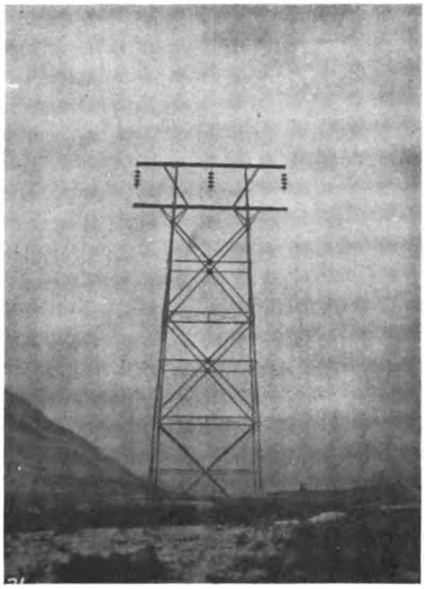


Fig. 4. Suspension Insulators on 60000 Volt Transmission Line

The insulators which are exposed to the elements gradually accumulate a film of dust which ordinarily will not affect the insulating value unless moisture is present. Insulators exposed in tunnels where there is a great deal of soot and dust, were afterwards tested electrically, and found to have very nearly the same insulation as originally, but under rain or dew test these arced over much below the test with a clean surface.

This type of insulator is not only used as a means of suspending transmission lines at high voltages, but at moderate voltages, it finds a wide field of application in the suspension of transmission lines across railroad rights of way and other points where the greatest mechanical safety and electrical protection is desired.

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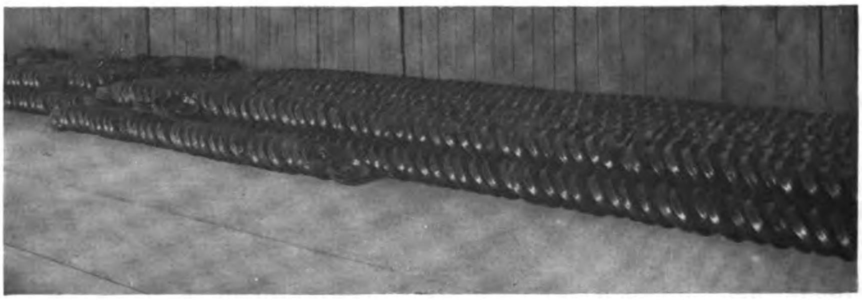


Fig. 5. Suspension Insulators in Factory of General Electric Company, Schenectady, N. Y.

VARIABLE RATIO CONVERTERS

("Split Pole" Converters)

PART I

BY CHAS. P. STEINMETZ

With a sine wave of alternating voltage, and with the commutator brushes set at the magnetic neutral, that is, at right angles to the resultant magnetic flux, the direct current voltage of a converter is constant at constant impressed alternating voltage. It is equal to the maximum value of the alternating voltage between two diametrically opposite points of the commutator, or to the "diametrical voltage," which is twice the voltage between alternating lead and neutral, or star or Y voltage of the polyphase system.

A change of the direct current voltage, at constant impressed alternating voltage, can be produced by either of the following methods:

(1) Changing the position angle between the commutator brushes and the resultant magnetic flux so that the direct current voltage between the brushes is not the maximum diametrical alternating voltage but only a part thereof.

(2) Changing the maximum diametrical alternating voltage (with constant effective impressed voltage) by wave shape distortion by the superposition of higher harmonics.

In the former case, only a reduction of the direct current voltage below the normal value can be produced, while in the latter case, an increase as well as a reduction can be produced; an increase, if the higher harmonics are in phase, and a reduction, if the higher harmonics are in opposition to the fundamental wave of the diametrical or Y voltage.

Variable Ratio by a Change of Position Angle Between Commutator Brushes and Resultant Magnetic Flux.

In the commutating machine shown diagrammatically in Fig. 1, let the potential difference, or alternating voltage between one point a of the armature winding and the neutral 0 (that is, the Y voltage, or half the diametrical voltage) be represented by the sine wave of Fig. 3. This potential difference is a maximum, e, when a stands at the magnetic neutral, A or B.

If, therefore, the brushes are located at the magnetic neutrals, A and B, the voltage between the brushes is the potential difference between A and B, or twice the maximum Y voltage, which is $2e$, as indicated in Fig. 3. If now the brushes are shifted by an angle τ, to positions C and D, Fig. 2, the direct current voltage between the brushes is the potential difference between C and D, or $2e \cos \tau$ with a sine wave. Thus, by shifting the brushes from the position A B, at right angles with the magnetic flux to the position E F, in line with the magnetic flux, any direct current voltage between $2e$ and zero can be produced, with the same wave of alternating voltage a.

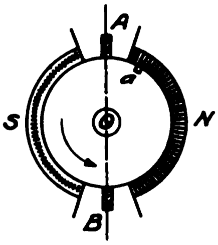


Fig. 1

As seen, this variation of the direct current voltage between its maximum value and zero, at constant impressed alternating voltage, is independent of the wave shape, and can therefore be produced regardless of whether the alternating voltage is a sine wave or a wave of any other shape.

With fixed position of the commutator brushes, obviously the magnetic field poles may be shifted in the opposite direction, by the same angle as shown in Fig. 4, A, B, C. Instead of mechanically shifting the field poles, they can be shifted electrically by having each field pole consist of a number of sections, and successively reversing the polarity of these sections, as shown in Fig. 5, A, B, C, D.

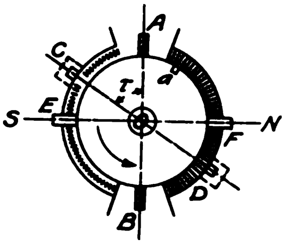


Fig. 2

Instead of having a large number of field pole sections, obviously two sections are sufficient, and the same gradual change can be brought about by not merely reversing the sections, but by reducing the excitation down to zero and bringing it up again in the opposite direction, as shown in Fig. 6, A, B, C, D, E.

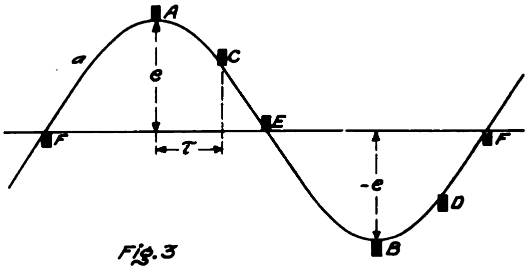


Fig. 3

In this case, when reducing one section in polarity, the other sections must be increased by approximately the same amount, to maintain the same alternating voltage.

When changing the direct current voltage by mechanically shifting the brushes with respect to the field poles, self-inductive sparking on the commutator would result as soon as the brushes came under the field pole faces, if the iron of the field poles were not kept away from the brush position by means of a slot in the field poles, as indicated in dotted line in Fig. 2 and Fig. 4 B. With the arrangement shown in Figs. 2 and 4, this is not feasible mechanically, and is therefore unsuitable. It is feasible, however, in such arrangements as those of Figs. 5 and 6, where the resultant magnetic flux is shifted electrically, to leave a commutating space between the polar projections of the field at the brushes, as shown in Fig. 6, and thereby secure as good commutation as in any commutating machine.

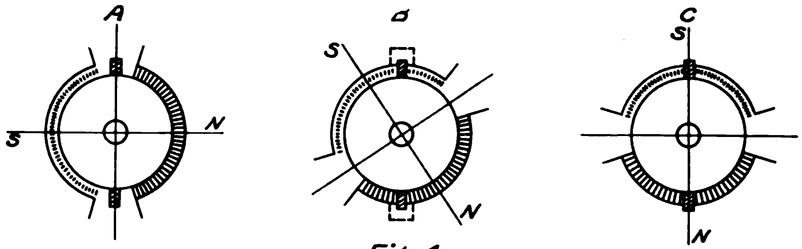


Fig. 4

Such a variable ratio converter then comprises an armature A, Fig. 7, with the brushes B B′ in fixed position, and field poles P P′, separated by interpolar spaces C C′ of such width as is required for commutation. Each field pole consists of two parts P and P_1, usually of different sizes, separated by a narrow space D, and provided with independent windings. By varying, then, the relative excitation of the two polar sections P and P_1, an effective shift of the resultant field flux and a corresponding change of the direct current voltage is produced.

As this method of voltage variation does not depend upon the wave shape, the alternating voltage wave can be made as near a sine wave as desired by varying the design of the field pole faces and the pitch of the armature winding. Usually, not much attention is given to this matter, as experience shows that the usual distributed winding of the commutating machine gives a sufficiently close approach to sine shape.

Armature Reaction and Commutation

With the brushes in quadrature position to the resultant magnetic flux, and with normal voltage ratio, the direct current generator armature reaction of the converter equals the synchronous motor armature reaction of the alternating energy current; therefore, at unity power factor the converter has no resultant armature reaction; while with a lagging or leading current, it has the magnetizing or demagnetizing reaction of the wattless component of current.

If, by shifting the resultant flux from quadrature position with the brushes by an angle τ, the direct current voltage is reduced by factor $\cos \tau$, the direct current, and therewith the direct current armature reaction, is increased by factor $\frac{1}{\cos \tau}$; as by the law of conservation of energy, the direct current output must equal the alternating current input (neglecting losses). The direct current armature reaction F therefore ceases to be equal to the armature reaction of the alternating energy current F_0, but is greater by factor $\frac{1}{\cos \tau}$:

$$F = \frac{F_0}{\cos \tau}$$

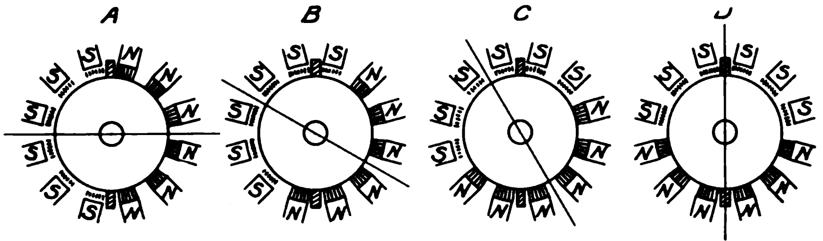


Fig. 5

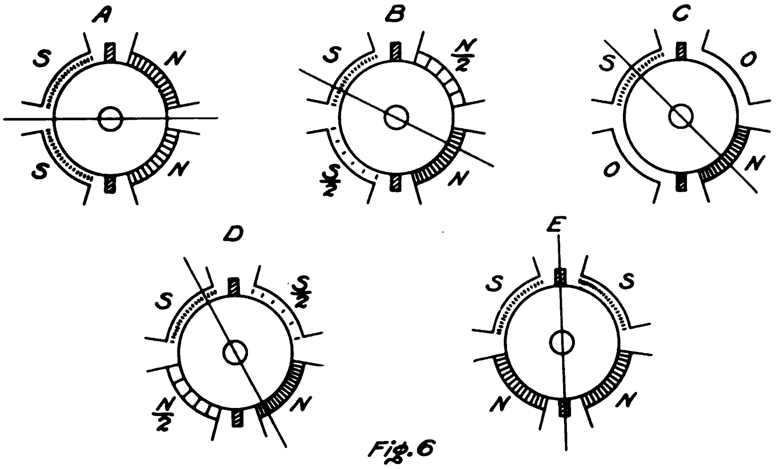


Fig. 6

The alternating current armature reaction F_0, at no phase displacement, is in quadrature position with the magnetic flux. The direct current armature reaction F, however, appears in the position of the brushes, or shifted against quadrature position by angle τ; that is, the direct current armature reaction is not in opposition to the alternating current armature reaction, but differs therefrom by angle τ and can therefore be resolved into two components, namely:

(1) A component in opposition to the alternating current armature reaction F_0, that is, in quadrature position with the resultant magnetic flux:

$$F'' = F \cos \tau = -F_0$$

This component is equal and opposite to the alternating current armature reaction, and neutralizes the latter.

(2) A component in quadrature position with the alternating current armature reaction F_0, and in phase with the resultant magnetic flux; that is, magnetizing or demagnetizing:

$$F' = F \sin \tau = -F_0 \tan \tau$$

This means that in the variable ratio converter, the alternating current armature reaction at unity power factor is neutralized by a component of the direct current armature reaction, but that a resultant armature reaction F' remains, in the direction of the resultant magnetic field; *i. e.*, shifted by angle $(90-\tau)$ against the position of the brushes. This armature reaction is magnetizing or demagnetizing, depending on the direction of the shift τ of the field.

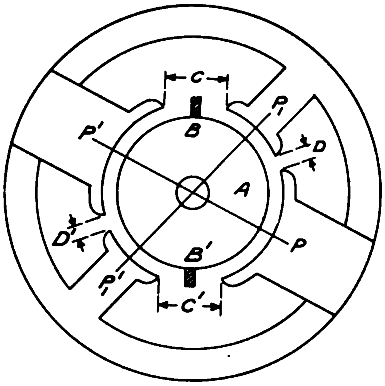


Fig. 7

It can be resolved into two components, one at right angles with the brushes and equal to

$$F'_1 = F' \cos \tau = F_0 \sin \tau$$

and one in line with the brushes, and equal to $F'_2 = F' \sin \tau = F \sin^2 \tau = F_0 \sin \tau \tan \tau$ as shown diagrammatically in Figs. 8 and 9.

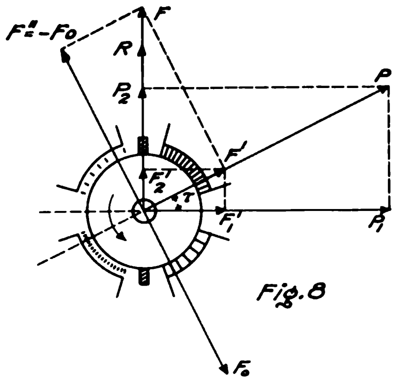


Fig. 8

There exists thus a resultant armature reaction in the direction of the brushes, which is harmful to commutation just as in a direct current generator, except that this armature reaction is only $F'_2 = F \sin^2 \tau$, or $\sin^2 \tau$ of the value of that of the direct current generator.

The value of F'_2 can also be derived directly, as the difference between the direct current armature reaction F and the component of the alternating armature reaction $F_0 \cos \tau$ in the direction of the brushes, or $F'_2 = F - F_0 \cos \tau = F\ (1 - \cos^2 \tau) = F \sin^2 \tau = F_0 \sin \tau \tan \tau$.

The shift of the resultant magnetic flux, by angle τ, gives a component of the m.m.f. of field excitation, $P_2 = P \sin \tau$ (where $P =$ m.m.f. of field excitation) in the direction of the commutator brushes, which is either in the direction of the armature reaction, thus interfering with commutation, or in opposition to the armature reaction, thus improving commutation.

If the magnetic flux is shifted in the direction of armature rotation, which is to say, if that section of the field pole is weakened towards which the armature moves, as in Fig. 8, the component P_2 of field excitation at the brushes is in the same direction as the armature reaction F_2, and is added thereto,

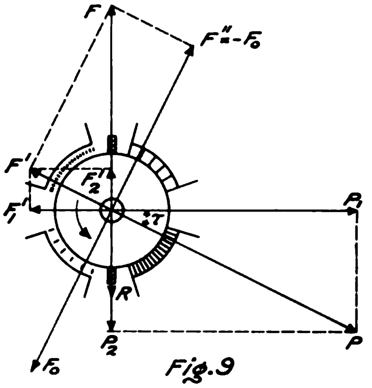


Fig. 9

thus impairing the commutation; such a converter is hardly operative. In this case, the component of armature reaction in the direction of the field flux F' is magnetizing.

If the magnetic flux is shifted in the opposite direction to the armature rotation, that is, if that section of the field pole which the armature conductors are leaving is weakened, as in Fig. 9, the component P_2 of field excitation at the brushes is in the opposite direction to the armature reaction F'_2, and therefore reverses it if sufficiently large, giving a commutating or reversing flux R which improves commutation; this arrangement is therefore used in such converters. In this case, however, the component of armature reaction F'

in the direction of the field flux is demagnetizing, and with increasing load the field excitation has to be increased by F', to maintain constant flux. Such a converter thus requires compounding, as by a series field, to take care of the demagnetizing armature reaction.

If the alternating current is not in phase with the field, but lags or leads, the armature reaction of the lagging or leading component of current superimposes upon the resultant armature reaction F', increasing it for lagging current in Fig. 8 and leading current in Fig. 9, and decreasing it for lagging current in Fig. 9 and leading current in Fig. 8. With the alternating current lagging by phase angle τ, under the conditions of Fig. 9 the total resultant armature reaction vanishes, that is, the lagging component of the synchronous motor armature reaction compensates for the component of the direct current reaction which is not compensated by the armature reaction of the alternating energy current. It is interesting to note in this case, that as regards heating, output based thereon, etc., the performance of the converter equals that of normal voltage ratio.

(To be Continued)

TESTING OF IRON, STEEL AND COPPER-STEEL CABLES FOR TRANSMISSION LINE

By Ira M. Cushing

The Bar Harbor & Union River Power Co. are developing the water power in the Union River at Ellsworth, Maine; and in the *Electric World* for September 21, 1907, a very good description of this interesting station will be found. Besides furnishing power locally, it is intended to transmit energy from this point to Bar Harbor on Mt. Desert Island, a distance of about 21 miles southeast, and to Veazie, near Bangor, about 25 miles to the northwest, at which point is located the water power plant of the Bangor Railway & Electric Co. From Veazie, power is distributed to Bangor and surrounding towns for lighting, power and railway. At Bar Harbor are located three 400 kw. single-phase step-down transformers, for obtaining 2300 volts for local distribution; and at Veazie are three 500 kw. single-phase step-down transformers, giving from 6600 to 6900 volts for supplying current direct to the existing system. At the main station in Ellsworth are three 500 kw. single-phase step-up transformers, changing the generated voltage from 2300 to 34,000 volts. The high tension transmission system is Y connected, with 19,600 volts to the neutral, and is operated with the neutral grounded.

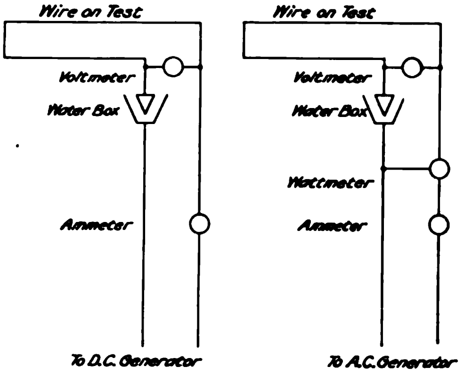


Fig. 1 Fig. 2

Arrangement of Meters, etc., for Testing Line

It is expected that the Veazie sub-station will take the greater portion of the transmitted power, and the line to this station will be of copper with an equivalent conductivity of No. 3 wire. The Bar Harbor sub-station is expected to take, for the present at least, but a small percentage of the load. This fact, in conjunction with the very high price of copper at the time the project was started, led the promoters to look into other kinds of metal conductors beside copper for this transmission line.

The writer was asked to assist in the test of three different kinds of wire, namely; $\frac{3}{8}$ in. double galvanized soft iron cable, $\frac{1}{2}$ in. double galvanized steel cable, and steel and copper cable about $\frac{7}{32}$ in. in diameter. These were made by John A. Roebling's Sons Co.

The $\frac{3}{8}$ in. cable consists of 7 strands of 0.120 in. diameter double galvanized wire. It is soft iron, is used in telephone work, and is specified as "Special EEB." The $\frac{1}{2}$ in. cable consists of 19 strands of No. 12 B.W.G.

(0.105 in. diam.) double galvanized steel cable. The steel-copper cable consists of a centre wire of 0.066 in. diameter, made of extra galvanized, extra strength plow steel, and weighs 13 lb. per 1000 ft. The six outside wires are twisted in the same direction, and are of hard drawn copper, each 0.066 in. diameter (No. 14), the six to weigh 80.2 lb. per 1000 ft. The tensile strength of the strand is 1800 lb. At the time of the tests (April to July, 1907), the ⅜ in. cable cost $12.35 per 1000 ft., the ½ in. cable about $21.00 per 1000 ft., and the steel-copper cable about $23.75 per 1000 ft. At the prevailing price for that time, the No. 4 solid copper wire would have cost approximately $28.30 per 1000 ft.

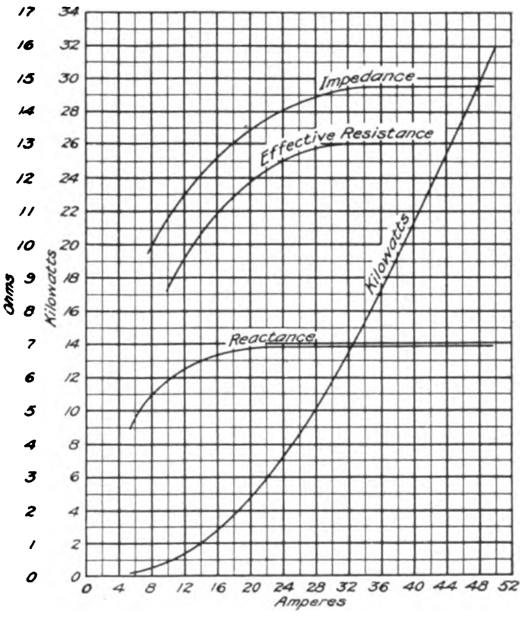


Fig. 3. Results Obtained with 3/8 in. Soft Iron Cable

These tests were made at Veazie, as the necessary power was available there. The wire for test was strung on poles for a mile up stream beside the railroad track. The return wire was placed 48. in. below the outgoing wire, on the same pole. The equipment for testing consisted of an A.C. and a D.C. generator, a water-box, and the following instruments: A.C. voltmeter, A.C. ammeter, indicating wattmeter, potential transformer, D.C. voltmeter, and D.C. ammeter.

On account of the high voltage of the A.C. generator, it was necessary to use a step-down power transformer. The generator was entirely free from the station bus so that its voltage could be varied between wide limits, which was done by controlling the exciter voltage. The D.C. generator was also used exclusively for the test. The water box was connected in series with the wire, and was used to get the finer variations in current. Readings were taken for approximately every 5 amperes from 0 to 50 amperes. Fig. 1 shows the connections for D.C. meters, and Fig. 2 for A.C. meters. A series of readings of current and voltage drop were taken with direct current, from which the resistance in ohms was calculated. With the voltmeter V, wattmeter W and ammeter A connected as in Fig. 2, a series of readings were taken with alternating current, giving watts, volts and amperes. From these were computed the impedance $R' = \frac{E'}{C'}$, where E' and C' are the A.C. voltage and current respectively. The effective resistance $R'' = \frac{W'}{(C')^2}$ where W' and C' are the A.C. watts and current; and the reactance $X = \sqrt{(R')^2 - (R'')^2}$. The results for the three different wires were plotted on curves, and are shown in Figs. 3, 4 and 5.

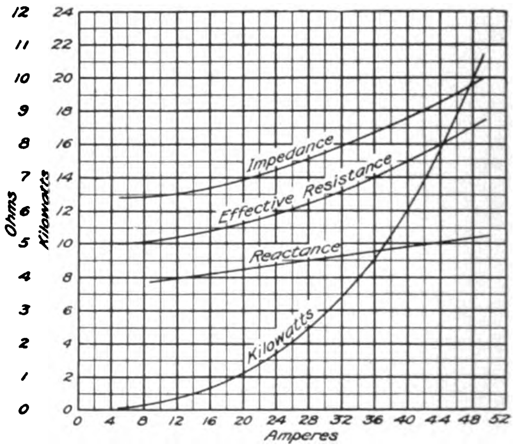


Fig. 4. Results Obtained with 1/2 in. Steel Cable

The wire tested was actually 2 miles long, that is, one mile out and one mile back; so the resistance obtained should be halved for resistance per mile. The result obtained for reactance gives the effect of one mile of wire upon another, and should, therefore, be considered the reactance per mile. The loss in watts is that of a single phase two wire circuit; therefore, for the loss in a three wire circuit with the same number of amperes, the results obtained in these tests should be divided by two and multiplied by three. For the losses in any line of given length, the above results should be multiplied by the length one way in miles.

The losses for this particular line, 21 miles in length, have been worked out for a given amount of power, namely; 1120 kw. at 30,600 delivered Y voltage, at 85 per cent. power factor. The formula used was:

$$E_0^2 = (E_1 \cos \theta + rI)^2 - (E_1 \sin \phi - 0.5 \times I)^2$$

in which E_0 is the voltage to the neutral at the generating end of the line; E_1 the voltage to the neutral at the receiving end; θ the angle of lag of the current; r the ohmic resistance of one wire; I the current; and ϕ the reactance for a double length of one wire of the transmission line.

Using the formula for the ⅜ in. soft iron cable, the following results were obtained:

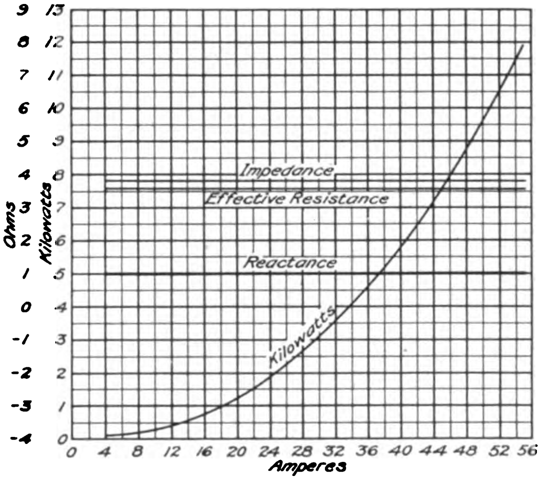


Fig. 5. Results Obtained with Steel-Copper Cable

The current required to deliver 1120 kw. at a potential of 30,600 volts, with an 85 per cent. power factor is 25 amperes. The potential to the neutral, $\frac{30,600}{\sqrt{3}} = 17,680$; *Cos* $\theta = 0.85$; *Sin* $\phi = 0.51$. From Fig. 3, the resistance for 21 miles is $\frac{6.56}{2} \times 21 = 68.88$ ohms. The reactance at 25 amperes for 21 miles is $6.9 \times 21 = 144.9$ ohms. Substituting in the formula, E_0 becomes equal to 20,178 volts; and E, the Y voltage, becomes $20,178 \times \sqrt{3} = 35,000$ volts. The voltage drop, therefore, is 4400 volts. The apparent energy loss is $4400 \times 25 \times \sqrt{3} = 191$ k.v.a. The $C^2 R$ loss is 64.5 kw. From the kilowatt loss curve of Fig. 3, the loss at 25 amperes is 8 kw. This is for two wires. For three wires, each 21 miles long, it will be $8 \times \frac{3}{2} \times 21 = 252$ kw.

For the ½ in. steel cable, curves for which are given in Fig. 4, the results for a 21 mile three-phase line are as follows: Generator voltage E, 33,600; volts loss, 3000; apparent loss, 130 k.v.a.; $C^2 R$ loss, 55 kw.; and loss as taken from the kilowatt loss curve of Fig. 4, 120 kw.

For the steel-copper cable, with the curves as given in Fig. 5, the results were: Generator voltage, 32,200; volts loss, 1600; apparent energy loss, 69.3 k.v.a.; $C^2 R$ loss, 38.3 kw.; and loss as taken from kilowatt loss curve of Fig. 5, 69.3 kw.

Attention is called to the fact that the test curves in Fig. 5 are for 9620 ft. of wire instead of 10,560 ft. or two miles. Therefore, in using these curves, the values obtained from them should be multiplied by 1.10 to deduce a figure for a double mile. For example, the reactance in Fig. 5 is 1 ohm. To obtain the reactance for a double mile, this should be multiplied by 1.10, giving 1.10 reactance ohms.

A No. 4 solid copper wire is about as small as can be used for this work; if this had been used, the losses for 21 miles of three-phase transmission would be: drop in voltage 1200 volts; with 25 amperes flowing, a loss of 52 k.v.a.; and a $C^2 R$ loss of 25.77 kw.

Recapitulation gives the following:

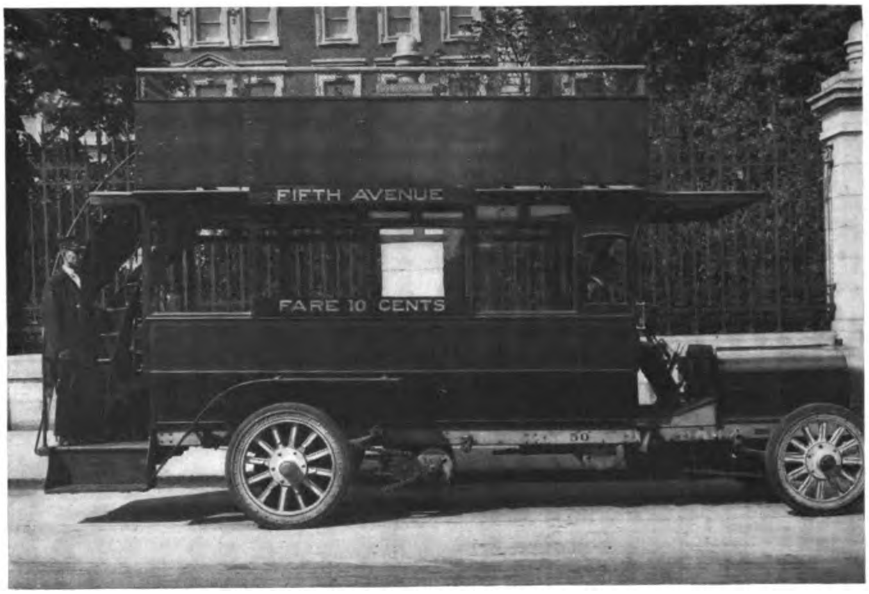
Size of Wire	⅜" Iron	½" Steel	Steel-Copper	No. 4 Copper
Volts Drop	4400	3000	1600	1200
Apparent loss (K.V.A.)	191	130	69.3	52
Kw. loss from loss curve	252	120	69.3	
C²R loss (kilowatts)	64.5	55	38.3	25.77

Before the time came, however, for ordering this wire, the price of copper had dropped, so the customer placed an order for aluminum wire. Up to date (June, 1908), the line has not been put up, so actual results are not obtainable.

GASO-ELECTRIC MOTOR OMNIBUSES ON FIFTH AVENUE, NEW YORK CITY

By H. S. Baldwin

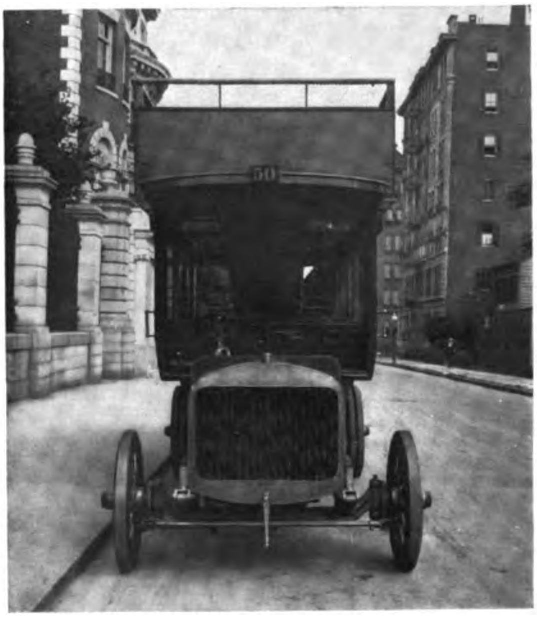
For many years the transportation facilities on Fifth Avenue, New York City, were not in keeping with one of the finest and most wealthy thoroughfares in the world. In the early days dilapidated omnibuses were drawn by decrepit horses, and the service was inadequate and precarious. Later, ownership of the omnibus line changed hands, and it was recognized that both good business judgment and the public demanded better horses, which were accordingly purchased and placed on the Avenue. This was a marked step in advance, but the old omnibuses still survived. Not that the operating company was wanting in a desire to improve matters, but with the advent of the automobile, some ten or a dozen years ago, it was obviously only a question of a short time before motor omnibuses would be available, and any extraordinary expenditure of money on horse-drawn equipment would be inexpedient from a business standpoint. They therefore turned to the new idea, and many an embryotic omnibus, either electric, steam, or gasoline, wended its way up and down the Avenue in an attempt to meet the demands of the public, as a rule, exciting as much criticism as did the horse omnibuses. None of these long survived the experimental period; but in the meantime the omnibuses with their animal motors were depreciating, and public opinion was not to be set aside.



Passenger Omnibus for Service on Fifth Avenue. New York Transportation Co.

The development of reliable and practical motor omnibuses had been made the subject of much study and experiment in Europe, competent engineers having utilized the material which had been rapidly accumulated in the art of pleasure automobile manufacture, adapting and proportioning it for commercial uses, both in the transportation of passengers and merchandise. The result was soon visible in the hundreds of motor omnibuses in London, Paris, and some of the larger Continental cities. It is not difficult to find a reason for the impetus that this line of activity obtained abroad, since the surface street railway is not so extensively found there as here.

Progress abroad was closely observed by American engineers and business men; and the New York Transportation Company, having acquired the Fifth Avenue Coach Company, purchased, about two years ago, a De Dion motor omnibus having a double deck body of the London type, capable of carrying thirty-four passengers in addition to a driver and conductor. Eighteen passengers were accommodated in crosswise seats on the upper deck, and sixteen inside.

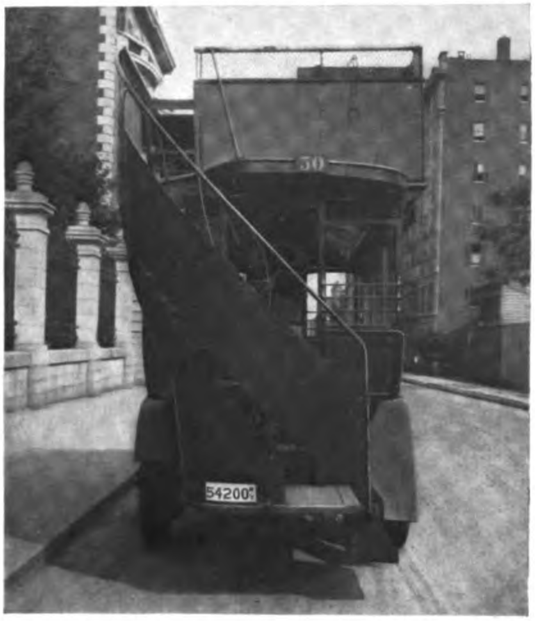


Front View of Omnibus

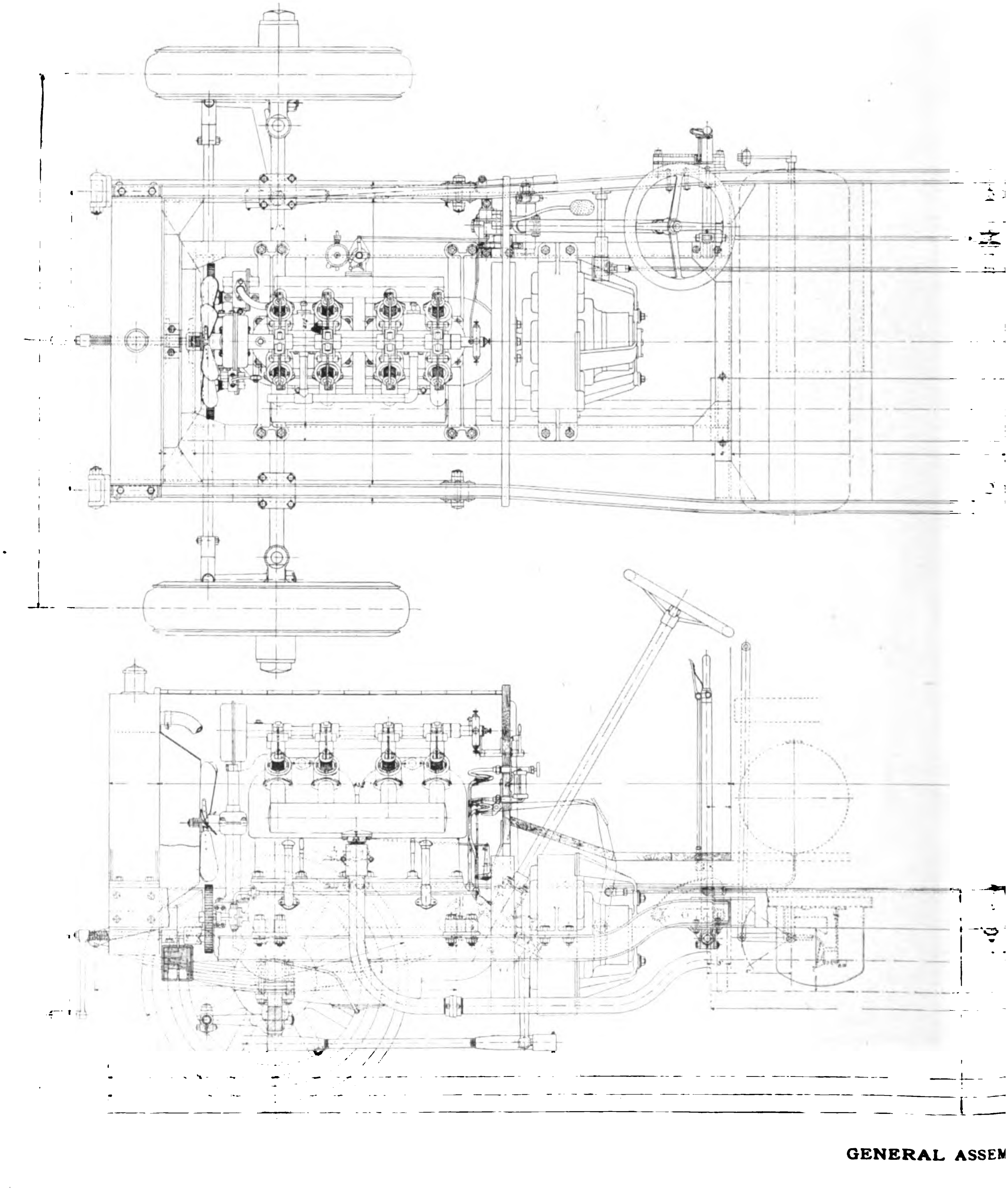
This was a step in the right direction; and about a year ago fifteen of the same type were placed in operation, being followed six months later by ten more, making a total of twenty-six, all of which are now in active service.

The prime mover of the De Dion omnibus is a 4-cylinder gasoline engine, which, through clutch and change gears, drives the rear wheels. In a general way the arrangement of parts is the same as is found in the modern touring car, except that the rear wheels are mounted on a dead rear axle and receive their motion from spur pinions engaging with large internal gears bolted to each wheel. This combination is known as the "De Dion drive," which, for omnibus work, has the advantage that it permits the use of the propeller shaft transmission without necessitating a live rear axle.

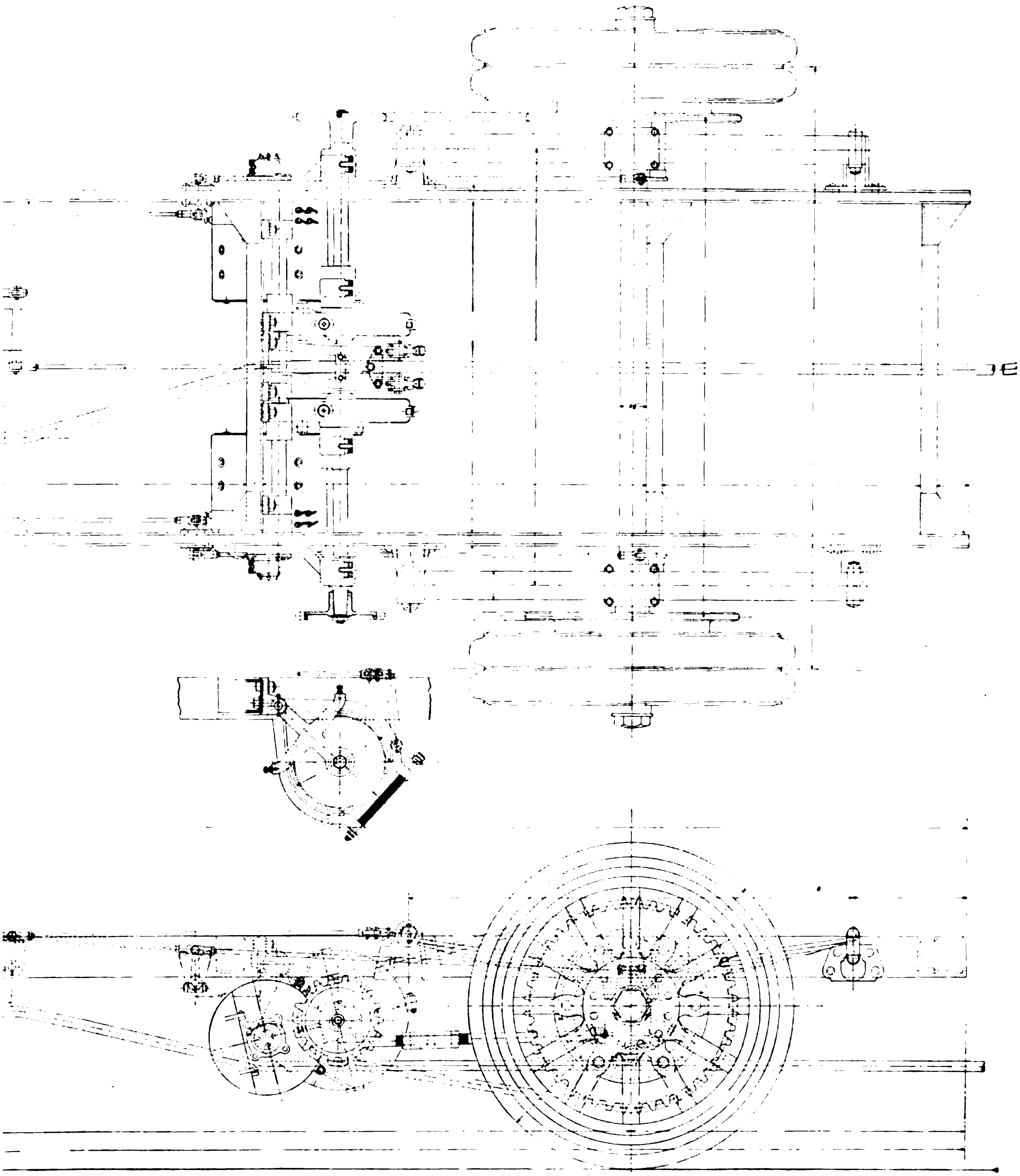
Information from abroad as to the maintenance of clash change gears of motor omnibuses, especially from London, indicates that the frequent stops and starts necessitated by the nature of the service and general traffic conditions introduce a serious item of expense not encountered in the touring automobile, where frequent change of gear is not required. Motor omnibuses may, for example, stop as often as once in every two blocks, of which there are twenty to the mile in New York City. On this basis, it is easily estimated that in a round trip on Fifth Avenue, of approximately eight miles, there would be eighty stops. Actual figures indicate from fifty to sixty stops during the hours of maximum traffic. Assuming again that each omnibus makes ten round trips a day, it is clear that the change gears receive frequent use, and, without doubt, much abuse. It is of course understood that at each stop some change of gear is necessary, unless on a down grade, even though the driver should start on



Rear View



GENERAL ASSEM



Y OF OMNIBUS

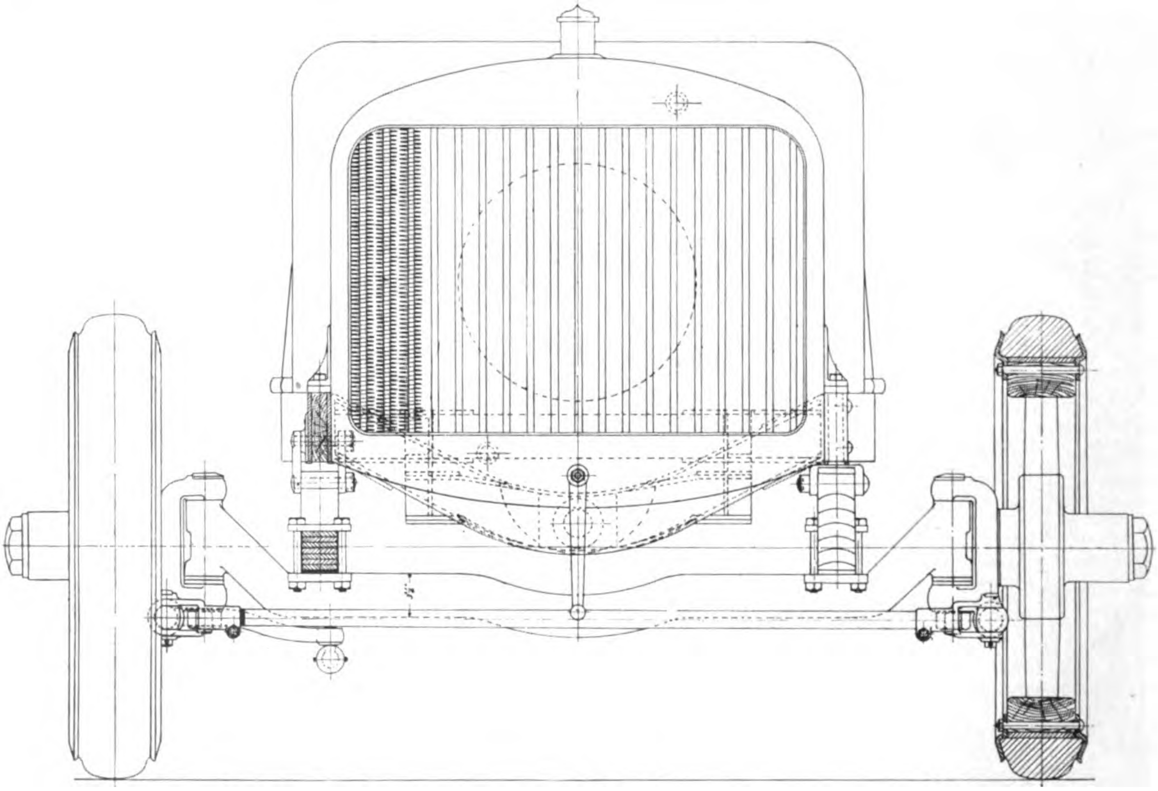
the second speed without going through first.

It is well known that a gasoline engine cannot give high torque at low speed; also, that this peculiarity demands some compensating device, usually a series of trains of spur gears, which can be shifted at will by the driver to meet the conditions of road grade or load at any given instant. Again, it is not practicable to reverse the gasoline engine; hence an additional set of gears must be used for running backwards. As has already been pointed out, some form of friction clutch is essential, since it would be impossible to shift gears under load without first disconnecting the engine.

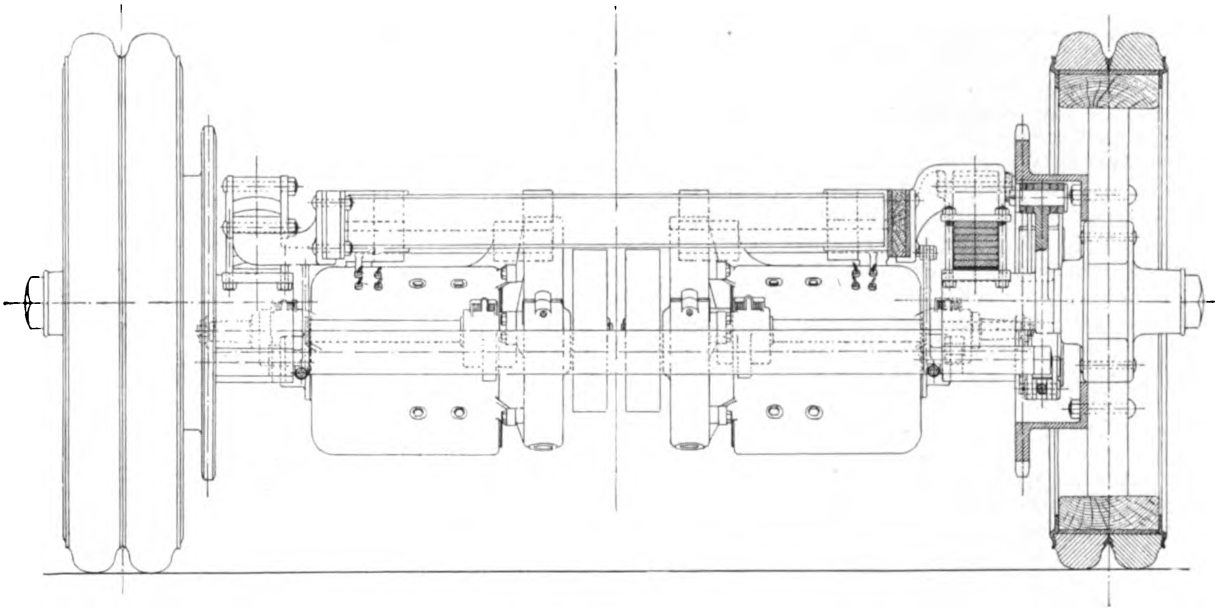
With automobiles of small size, carrying from one to six or seven passengers and used mostly for touring or short runs, little objection is found to clash change gears; since as a rule such cars have relatively large engines, and are often run for many miles without a change of gear. With the public motor omnibus it is different, and engineers throughout the world have long sought a satisfactory solution of the problem. Given a gasoline motor omnibus, find the transmission or change gearing which shall correct the lack of flexibility of the gasoline engine as to torque; give reversibility; insure smooth yet rapid acceleration; and withal be simple and have low cost of maintenance. To fulfill the conditions and solve the problem is to eliminate one of the greatest objections to public motor service, especially in large cities.

The series electric motor has many of the desired characteristics; namely, high torque at low speeds, ability to pick up rapidly, and to reverse without gearing. If two series motors are used to drive the omnibus, one for each wheel, two objects are gained: first, the motors may be operated in series or parallel with each other, giving either large torque or high speed; and second, when the motors are run in parallel—and on Fifth Avenue the motors are in parallel for most of the time—each will do its own work, and the danger of skidding, which is present when a mechanical differential gearing is used, is largely eliminated.

The series motor is to a marked degree an automatic torque and speed changing device,



Front Elevation



Rear Elevation

reversible, and of simple, durable construction, not easily injured, and at the same time easily repaired. It has but one rotating part, the armature, provided with two plain bearings; and there are no other highly machined or closely fitted parts, of expensive material, as in the mechanical transmission. The motor is controlled by a small drum switch, and does not require a multiplicity of levers and rods, all in proper adjustment and alignment with relation to each other. Lubrication of the motor is most simple. When two motors are used, as on the omnibus, no accurate alignment is required, and each can be suspended from the running frame or dismounted with little delay. There is no complicated countershaft or propeller shaft with several universal joints.

In order to profit by these advantages, there must be a supply of electric energy to drive the motors. The storage battery first offers itself, but owing to its comparatively small capacity, rendering either frequent change of battery or long intervals of charging necessary, it has not been found suitable for long distance omnibus work.

If, now, a specially designed generator be directly coupled to a gasoline engine, so as to furnish energy to the motors, the mileage of the omnibus will only be limited by the supply of gasoline. The engine and generator together need not weigh over 1000 to 1200 pounds for a 34-passenger omnibus. A generator suitable for the purpose can be made of simple construction and the gasoline engine of to-day presents no unusual difficulties. The generator should preferably be compound wound, with drooping characteristic, and designed electrically for practically constant output. It should be able to withstand heavy overloads for short intervals of time, with good commutation throughout its operating range. Further, it should be self-exciting, otherwise sluggish acceleration would result; and finally, it should be mechanically substantial and rugged. Such a generator can be short-circuited at full load, or high overload, without stalling the gasoline engine.

The General Electric Company has developed apparatus which meets in a practical manner the requirements of an ideal transmission or change gear, as set forth above, and has built for the New York Transportation Company, a number of equipments for omnibuses, embodying the electric transmission.

The accompanying illustrations will give a good idea of the appearance of these omnibuses; while the assembly drawing will show the relative location of the several parts of the motive system.

The bodies are of the standard London type, and the running gears are specially designed to accommodate the electric motors and generator. While there is a controller in the electric circuit, it serves mainly for reversing or throwing the driving motors into series connection for hill climbing or very rough roads. Ordinarily, it is not used during a trip on the Avenue, since it is not necessary to open the generator circuit; for, by reducing the engine speed, only sufficient energy is developed to move the omnibus slowly. This action is equivalent to letting the friction clutch slip, in the case of an omnibus with mechanical transmission.

All motor vehicles suitable for use on highways must have a steering gear and one or two brake levers. With the ordinary gasoline omnibus there are provided, in addition to these, the change gear lever, the throttle and spark levers, and the clutch pedal. With the gaso-electric omnibuses, aside from steering wheel and brake levers, there is only one control lever required during the round trip from 88th Street to Washington Square. This is a spring-returned throttle pedal operated by the driver's right foot. If, for any reason, the driver were thrown from his seat or injured, the omnibus would very shortly come to rest, as the throttle would automatically close when released.

It may be thought that the electrical apparatus described would have considerably more weight than has the mechanical transmission, but actual comparison under the same conditions shows that the gaso-electric omnibus outweighs the gaso-mechanical omnibus by less than 100 pounds, its weight being 9150 pounds complete with supplies. The passenger load brings the total weight up to about 14550 pounds.

Road trials have demonstrated that the gaso-electric omnibus has a speed, when loaded, of about 18 miles per hour on the level. For straight-away service, it will run from four to five miles on one gallon of gasoline; but with the frequent stops on the Avenue, these figures are somewhat reduced.

A very noticeable feature, due to the electric transmission, is the smooth acceleration of the new omnibus. Measurements show this to be about 1¼ miles per hour per second, or substantially that of the omnibus with mechanical transmission. The acceleration of the gaso-electric omnibus is somewhat deceptive, owing to the freedom from the shock which accompanies the operation of clutch and change gears in the case of an omnibus of conventional construction. This advantage is especially pleasing to the passengers.

Another important feature of the gaso-electric omnibus is its quietness of operation, which can be accounted for by the comparatively small number of gears required in the transmission with chain drive.

It is claimed for electric transmission that it will maintain its full original efficiency with little repair, even after long usage, while mechanical gearing will require constant attention, and unless kept in good condition will decrease rapidly in efficiency.

A brief description of the generator may be of interest. It is a six pole machine, each pole being slotted on the entering side, forming a small auxiliary pole about which most of the series turns are wound. By saturation of this tip, series excitation is limited, and a drooping characteristic is the result. A further effect of this saturation is to give good commutation at times when the field is otherwise weak. Several series turns entirely encircle the pole, the shunt winding being placed over all. Here is, in effect, a commutating pole generator, with high overload characteristics and fine commutation at all loads; which is quickly self-exciting, and at the same time is of light weight. This machine is known as the TD-6-7½ kw. generator, and is rated at 125 volts, 60 amperes, at 900 r.p.m. It may be run at 100 per cent. overload for two hours with a 70° C. rise of temperature, and at 50 per cent. overload continuously. It has an efficiency of 85 per cent. at normal load, and weighs about 435 pounds. When in operation it has been short-circuited without stalling the engine, taking 285 amperes at 2 volts.

The two electric motors are of the GE-1026 back-geared type, rated at 125 volts, 30 amperes. These are practically small railway motors having the back gear brackets and supporting lugs all cast on the magnet frame in a one-piece steel casting. A hardened steel herring bone pinion, with teeth of large pitch, meshes with a phosphor bronze gear, both being enclosed in an aluminum alloy housing which is grease tight. All bearings are waste-packed lubricated. Provision is made on the inner end of the countershafts for motor brake drums.

The gasoline engine which is used to drive the generator is of special design, and is of the 4-cycle type with 4 cylinders, each 5 in. by 5 in. It is rated at 27–30 h.p., and weighs about 700 pounds complete. All valves, both intake and exhaust, are located in the cylinder heads, which arrangement tends to high efficiency and power for a given displacement.

The chassis or running gear of the new gaso-electric omnibus is designed and made specially for the purpose. The following is a short description of its principal features:

The running frame is of double armored wood with pressed steel cross members, all hot riveted with stout gussets and corners. The sub-frame for the engine and generator has three points of suspension, which arrangement relieves the motive unit from undue twists and strains. Both electric motors are suspended from a strong cross member, side by side, somewhat forward of the rear axle. As has already been stated, each motor is complete with back gearing. Transmission from the motor countershafts to the driving wheels is by roller chain of 1¾ in. pitch, and the total ratio of reduction of gears and sprockets is about 14½ to 1. Long half springs support the omnibus at front and rear in an effective manner, resulting in easy riding. Steering and driving wheels are of artillery design, 34 and 40 in. diameter, respectively. The tire equipment consists of four inch single solid motor tires for the steering wheels, and three and one-half inch twin tires of the same kind for the driving wheels. The front axle is a steel forging, the steering wheels being mounted on pivots of the inverted Eliot type. An axle of the built-up construction is used at the rear. This consists of a large steel tube with heavy walls, on each end of which is securely fastened a steel casting, forming not only anchorage for the main driving wheel brakes but a support for the axle arm stubs. All wheels run on conical roller bearings. The chassis has a wheel base of 168 in., with front and rear wheel gauges of 67½ in. and 72½ in., respectively. There are two independent sets of brakes of liberal dimensions. A foot pedal operates the two motor brakes, while a hand emergency lever actuates two large internal brakes on the driving wheels. Steering is effected in the usual manner by means of a hand wheel operating through gear and sector.

On trial tests, the first gaso-electric omnibus chassis, with a load of 6500 pounds, was run up grades of 12 to 15 per cent. without stalling. At this time the two motors were in series connection. For grades of 4 to 5 per cent. it was not necessary to change from the parallel position.

It is thought that there is a large field for the equipment which the General Electric Company has developed, and the operation of the new omnibuses is being watched with much interest.

MOTOR DRIVEN ENVELOPE FACTORY

By A. F. Hemingway

Chicago Small Motor Department,
General Electric Company

The Illinois Envelope Company, one of the largest manufacturers of envelopes, ranging in design from the artistic and dainty conception for social use to the ordinary business variety, having outgrown their original plant at Centralia, Ill., decided to build a new plant at Kalamazoo, Mich., as this point offered a number of advantages.

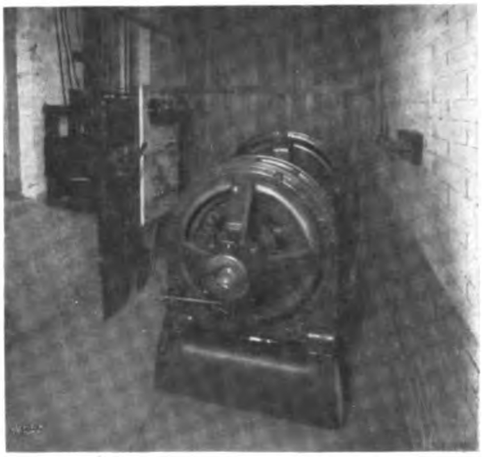


Fig. 1. 40 Kw. Motor Generator Set and Switchboard 2300 Volts A.C. to 250 Volts D.C.

Having found in their old factory that the steam-line shaft drive was not only a source of dirt and inconvenience, but likewise expensive to operate, the Company naturally decided on the modern, clean, and economical electric drive for their new three story bui ing. Arrangements were made to secur electric power from the Commonwealth Company, of Michigan. For heati water system was installed aft sideration. The plant has factory operation for som years.

In conversation, Mr. Tapley, Secretary and Manager, stated:

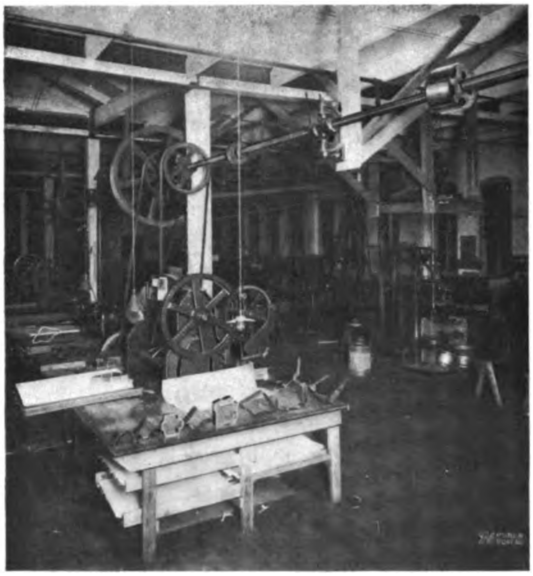


Fig 2. Cutting Machine Operated from Line Shaft Driven by 15 h. p. Motor

"The 55 General Electric motors have given us complete satisfaction since their installation some two years ago. We find the electric motors very convenient and economical to use, being able to turn out more envelopes per machine per day than ever before."

From the number of motors it will be seen that the Illinois Envelope Company fully appreciated the advantages of individual drive, which is employed throughout with the exception of two group drives.

Although the central station supplied alternating current, it was decided to adopt direct current motors, as many of the machines required variable speed, which could more readily be obtained with direct current than with alternating current motors. To change from alternating to direct current, a compact motor generator set was installed, taking current from the Commonwealth Power Company's lines at 2300 volts, thereby avoiding the use of an alternating current transformer.

Fig. 1 shows the motor generator set and accompanying switchboard, which are located in a locked room to prevent the entrance of any unauthorized person.

A brief description of the various operations, together with the equipment employed in the manufacture of envelopes, may not be out of place. The work is divided into three sections; namely, the cutting, folding, and printing departments. In addition to these, there is a box factory for making paper boxes, a machine shop, and the shipping and receiving departments.

The raw paper stock first passes to the cutting machines. These and the machine shop are so located as to be economically driven from a line shaft to which is belted a 15 h.p. motor as shown in Fig. 2. In cutting out the envelopes it is the practice to lay a full ream of paper on a rolling platform or table. The cutter or die is placed on the stock, and when the plate or press head is up, the paper is slid underneath. Thus at one stroke 500 envelope forms are produced.

The next step in the production of an envelope is the folding. The machines (Fig. 3) do this work and entirely complete the envelope, applying the vegetable gum,

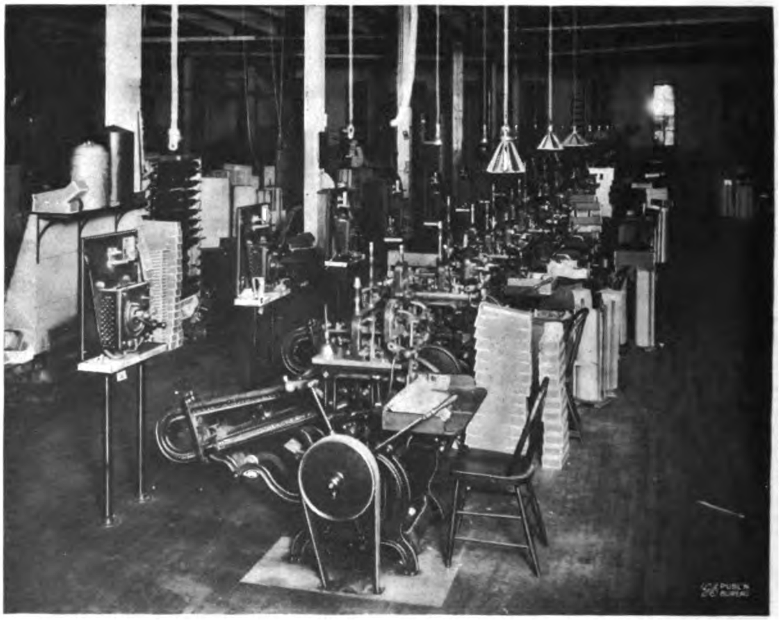


Fig. 3. Envelope Folding Machines Driven by 3/4 h.p. Constant Speed Motors Average Capacity for a Ten Hour Day, 60,000 to 70,000

sealing the closed portion, and discharging the completed envelope. The machines mechanically count off the envelopes in quantities of 25, the 25th being out of line with the others by about one-half inch as they are fed mechanically along the traveling conveyor at the rear. Each cutting machine can take care of a large variety of different styles of envelopes. On the other hand, the best results are obtained with the folding machine by confining each machine to one size. There are 38 different folders (Fig. 3), fifteen of which are driven by Type CQ $\frac{3}{4}$ h.p. constant speed motors, while the remaining twenty-three are driven by CR $\frac{3}{4}$ h.p. motors, having a range of speed of from 600 to 900 r.p.m. The variable speed is obtained by shunt field control. The controller has five starting points and eighteen points for speed variation. The variable speed motors increase the production greatly where different qualities of stock are used for a given size envelope, as for instance, when soft paper is used, which folds more readily and consequently can be worked more rapidly than the superior grade of hard calender. The variable speed qualities of the motor take care of this change in stock most economically. The motors are mounted on the ceiling below, belted up through the floor.

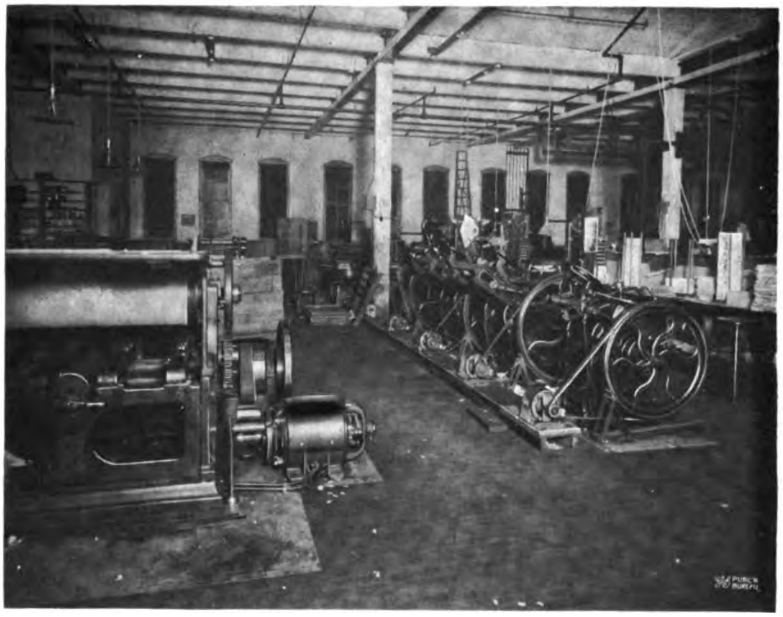


Fig. 4. Job Presses Driven by 1/4 h.p. Motors
Flat Bed Press Driven by 3 h.p. Motor

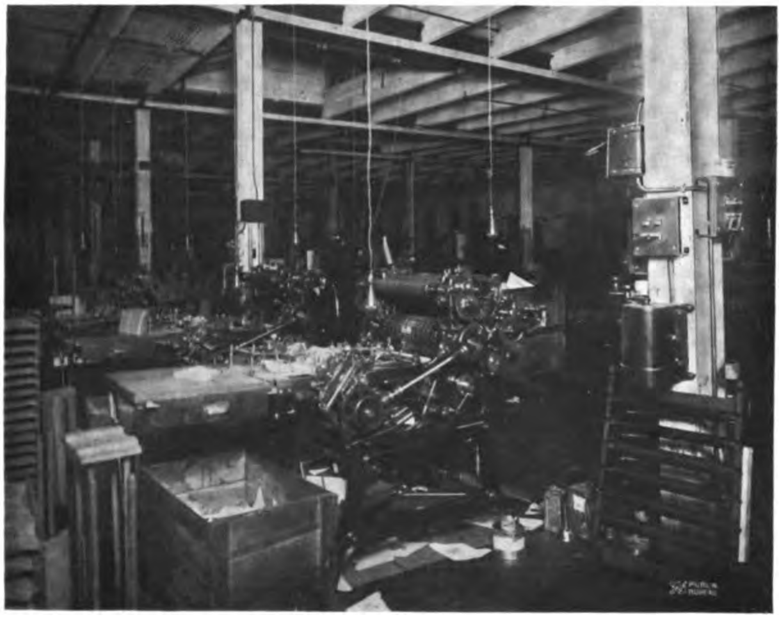


Fig. 5. Rotary Printing Presses Operated by 2 h.p. Motors
Capacity for a Ten Hour Day, 60,000 to 100,000 Blanks

The printing department consists of four job presses for small printing in envelope corners, etc. Fig. 4 shows the individual constant speed CQ $\frac{1}{4}$ h.p. motors belted to the fly wheels of these job presses.

Only a comparatively small proportion of the envelopes are now printed after the envelope is completed, as it is much better practice to do this work upon either the stock sheets or the cut blanks, as it avoids handling, etc. The job presses take care of the printing on the completed envelope, and two flat bed presses, each driven by a CR 3 h.p. motor, with a speed variation of 1½ to 1, do the printing on the stock sheets. One of these presses is shown to the left in Fig. 4.

For printing the cut blanks four automatic presses are used, each driven by a CR 2 h.p. motor with a speed rating of 1½ to 1. Fig. 5 shows a group of these automatic presses which only require that the operators maintain a supply of blanks in the feed mechanism and remove the printed forms that are mechanically stacked up under the press.

The cardboard boxes in which the envelopes are packed are made up by the box factory. The machinery located here is all driven from a line shaft by a 5 h.p. motor. These paper boxes usually contain 500 envelopes, although the smaller sizes are packed 1000 in a box. The completed envelopes now pass on to the shipping department ready to be packed in the wooden cases and shipped to the customer.

ELECTRIC LOCOMOTIVES FOR THE GREAT NORTHERN RAILROAD

The illustration on page 194 of this issue of the Review shows one of the new electric locomotives that are to be used by the Great Northern Railroad for hauling both their passenger and freight trains through the Cascade tunnel.

The length of this tunnel—about two and three-quarters miles—together with the fact that it is unequipped with ventilating shafts of any description, has rendered the employment of some motive power other than the steam locomotive an imperative necessity; for in addition to the danger arising from the gases emitted by steam locomotives, and the possible obscuring of signal light by smoke, the accumulation of sooty matter has given rise to a slipperiness of the rails that materially increases the difficulties of the grade, which, throughout the tunnel is 1.7 per cent.

To meet the requirements of the traffic, four of these locomotives have been ordered.

Each of these units will have a weight of approximately 113 tons, this weight being entirely on the drivers, and will be equipped with four 400 h.p. three-phase induction motors mounted on two articulated bogie trucks.

The locomotive units are designed to be operated by the Sprague-General Electric Multiple Unit control, so that three or four may be operated from one controller on any unit. In normal operation, two of these units will haul a train having a gross weight of from 1200 to 1500 tons up a grade varying from 1.6 to 2.2 per cent. at a speed of 15 m.p.h.

The motors will be wound for 500 volts per phase, and will be fed from two step-down transformers located on the car. They will be controlled by resistance steps in the secondary or armature circuit.

On down grade, the motors will tend to control the train by regeneration, and at any speed in excess of 15 miles per hour, will return energy to the line, thus tending to assist other trains that may be ascending the grade at the time. If, at the moment, there is no such train to utilize this returned energy, it will be dissipated by water rheostats at the power house. An additional advantage in thus using the regenerative feature of the motors on a descending grade, is, of course, the braking effect and the consequent saving of brake shoes and tires.

The power will be supplied from a generating station, located on the Wenatchee River, and distant about thirty miles from the tunnel. The generating equipment will consist of two 2000 kw., 25 cycle, three-phase generators, which will be driven by water power. From the station, the power will be transmitted at 30,000 volts by means of duplicate transmission lines, and will be stepped down by transformers at the mouth of the tunnel to 6600 volts. The locomotives will take the current from an overhead wire, which will be of a modified catenary type, utilizing the new fish tail strain insulator of the General Electric Company.

THE LOW PRESSURE STEAM TURBINE

By Charles B. Burleigh

The prime object of this paper is to call to your attention a recent engineering development which will effect immense gains in capacity and economy in existing steam power plants without involving any sacrifice or abandonment of any part of the present equipment, accomplishing this result with a minimum of additional investment.

While the reciprocating steam engine is comparatively a highly efficient piece of apparatus for utilizing the available energy of steam between boiler pressure and atmospheric pressure, it is relatively inefficient for utilizing the available energy of the steam in its lower ranges, below atmospheric pressure.

On the other hand, the supremacy gained by the steam turbine has been largely due to the fact that it as efficiently utilizes the available energy of steam in the lower pressure ranges as in the higher, and as there is as much available energy in steam below the atmospheric line as above it, we are led to the investigation of the results to be obtained from the use of the reciprocating unit in its most profitable field (the higher pressure ranges), combined with the turbine for the most efficient transformation of the lower pressure ranges.

In order that we may discuss this situation comprehendingly, it is necessary that the writer digress to the extent of investigating with you some of the characteristics of steam expansion, until recently little appreciated. Let us examine Fig. 1, which shows diagrammatically two expansion curves of a given volume of steam from an absolute pressure of 120 pounds. Curve No. 1 represents its isothermal expansion, or expansion at constant temperature, varying in pressure inversely as the space occupied.

Curve No. 2 represents its adiabatic expansion, or expansion doing work without loss or gain of heat from an external source.

From the fact that the derivation and consequent discussion of the isothermal curve is much the simpler, and also from the fact, as you will note from the diagram, that the two curves correspond so closely, I have selected the former for discussion, but do so with some hesitancy, fearing I may be misunderstood as wishing to convey the idea that the expansion of steam in the turbine is isothermal. It is not, but is absolutely adiabatic, and the consideration of this curve only in the result of our deduction eliminates the possibility of error.

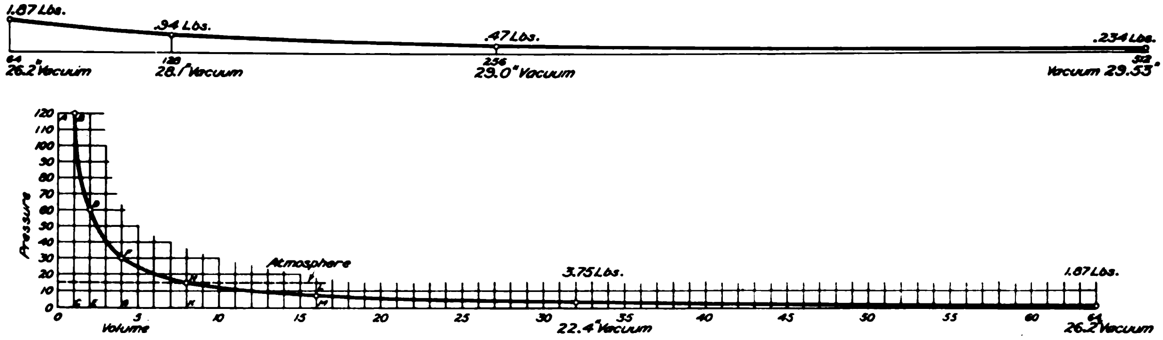


Fig. 1. Steam Energy Available through Expansion

The pressure scale of curve, from 1.87 lb. to 0.23 lb. is 10 times that above 1.87. The volume scale of curve from 64 to 512 is 1/10 of that above 64

Now, considering curve No. 1, since the height of this diagram represents pressure, and the length volume, its area, which is the product of its length by its average height, is proportional to the energy available, which, again, is the product of the average change in pressure by change in volume. This is as true of a portion of the diagram as it is of the whole.

The area B D E C, for example, represents the energy generated by the expansion of the volume A B at 120 pounds pressure, to twice its volume; in which case, if the expansion is isothermal, the pressure will be 60 pounds.

The conclusion that we arrive at from this diagram is that the energy generated by the expansion of a given weight of steam depends not upon the particular pressures between which the steam is expanded, but upon the number of times it is expanded. Remember, however, that change in volume is the result of change in pressure.

The diagram shows nine successive expansions, each expansion doubling the volume.

The first expansions, being more conveniently divided into equal squares, will bring more prominently to your notice the fact that each expansion means equal available energy; or, in other words, that each time the volume is doubled the energy step is equal, and the expansion from 15 to 7.5 pounds represents as much work as from 120 to 60. Steam expanded from 1.87 to 0.234 pounds represents as much work as when expanded from 120 to 15 pounds; further, as there are six expansions below the atmospheric line as compared with but three expansions above, if we can as efficiently use these, it will be possible to derive as much benefit in work from the lower ranges of the diagram as from the higher ranges, if not more.

It is unfortunate that the whole diagram could not be drawn to the same scale, large enough to make the equivalence more apparent; but its careful consideration shows us that the process is continuous, and that the expansion of a given weight of steam from two pounds to one pound absolute, or from 26 to 28 inches vacuum, is capable of as much work as the expansion of the same weight of steam from a pressure of 200 to 100 pounds.

A comparison of the different volumes represented by the adiabatic curve No. 2, will at once bring to your notice the comparative areas of cylinders of reciprocating engines necessary to efficiently utilize the energy to be derived from these low ranges. Thus, a piston, to effectually use the energy of the sixth expansion, must necessarily present an area sixty-four times greater than that which economically utilizes the energy of the first expansion.

Here we have only expanded our steam to a little less than two pounds absolute. Continuing our expansion to one-quarter pound absolute, at 29.5 inches vacuum, we find that we have increased its volume approximately 512 times.

Therefore, it will at once be seen that the reciprocating engine is totally unfitted for deriving anywhere near full benefit from these lower ranges.

For example, if a piston 12 in. in diameter efficiently utilized the energy of the first expansion, one of approximately 22.6 ft. in diameter would be required for the ninth expansion, for the same relative efficiency. You will at once appreciate the fact that these conditions are prohibitive. For these reasons, until the advent of the steam turbine, it was not good engineering to attempt to benefit from the low pressure ranges.

This brings us by a rather circuitous route to the subject of this paper.

The Low Pressure Turbine

The low pressure turbine is designed to take steam at one pound gauge pressure and efficiently utilize its energy to within one-half pound absolute pressure, or, in other words, to a 29-inch vacuum, with water rates of from 30 to 50 pounds per kilowatt-hour at the switchboard, depending upon size and local conditions.

The low pressure turbine can be advantageously applied in any case where reciprocating engines are now used, and such application will always afford a large improvement in economy, and increase the power output without an increase of boiler plant.

This applies in any case, whether engines are now operated condensing or non-condensing, delivering their output electrically or mechanically; and it also applies to engines which operate on intermittent loads, since the delivery of low pressure steam can be equalized by suitable steam regenerating apparatus.

In many existing plants engines are operated non-condensing because cooling water is not conveniently available.

Such practice may be legitimate with reciprocating engines, because the gain by condensation with engines is comparatively small and, in many cases, may not pay for the additional complication and expense, incident to the installation and operation of cooling towers or condensers.

If low pressure turbines are used, however, we can expect to obtain about as much power from the turbine working below atmosphere as we do from the engine working above atmosphere, and there can be no question as to the economy of installing condenser facilities and low pressure turbines, even where cooling towers are required.

There are already in existence plants where low pressure turbines have been installed in connection with engines previously used non-condensing, and by such installation, in conjunction with cooling towers, the output of the plant has been practically doubled without any addition to fuel consumption or attendance. Permit me to be specific in this statement, and cite a 1,000 horse-power non-condensing engine plant operating 3,000 hours per year, with a fuel consumption of 2.5 pounds of coal per horse-power, or 3,750 short tons of coal per year.

By the addition of a 1,000 horse-power low pressure turbine, with a suitable cooling tower made necessary by local conditions, and capable of maintaining a 28-inch vacuum, the plant was made to deliver 2,000 horse-power 3,000 hours per year, with 1.25 pounds of fuel per horse-power hour, or 3,750 short tons of coal per year. The plant, doubled in output, required no addition to the boiler equipment, nor was any additional labor made necessary.

The most ready field for the introduction of low pressure turbines is found in existing condensing plants which operate with reciprocating engines. In such plants, immense gains can be accomplished by the use of low pressure turbines either with existing condensers or with improved condensing facilities. The gain by high vacuum in turbines is so much greater than in engines that it will generally be worth while to install condensing facilities, including the pumps, of the most improved kind. Where low pressure turbines are installed, the exhaust pressure of engines will be above the atmosphere. There will, therefore, be no air leakage around piston rods and valve stems, and it will be possible to maintain a better degree of vacuum than that which is generally experienced in condensing engine plants, where there is more or less leakage of air, and but little encouragement for the production of high vacuum.

The possibilities of the low pressure will be more readily understood if we consider the available work in different ranges of steam pressure. If saturated steam operates from a pressure of 150 pounds gauge to a pressure of one pound above the atmosphere, the available energy is about 132,000 foot pounds per pound; and if saturated steam operates from a pressure of one pound of steam above the atmosphere to a vacuum of 28½ inches, the available energy is 146,000 foot pounds per pound of steam. In a mixture of steam and water issuing from an ordinary steam engine, exhausting at a pressure of one pound above the atmosphere, the above available energy is reduced to about 132,000 foot pounds per pound when working to a vacuum of 28½ inches. Thus, under these very ordinary conditions, there is as much work available in the low pressure ranges as in the high.

In most condensing engines the gain over non-condensing conditions does not exceed 30 per cent., even under the most favorable conditions of load; and under overload conditions the gain by condensing is much smaller. In most cases a reciprocating engine, when operated non-condensing, will give at least 75 per cent. of the output for the same steam as when used condensing. This steam, if exhausted into a low pressure turbine with good condensing facilities, will produce nearly, if not quite as much work as the high pressure steam in the engine. Therefore, under ordinary conditions, a net gain of 100 per cent. over existing condensing engine service can be had by installed low pressure turbines; and under overload conditions, where the efficiency of the engine falls off, and where its gain by vacuum is greatly diminished, the advantages will be much greater.

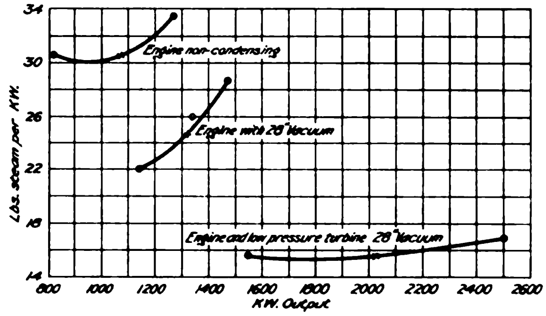


Fig. 2. Tests of a 22x44x42 Rice Sargent Engine with D. C. 250 Volt Generator Compared with Results Obtainable from Same Engine in Connection with Low Pressure A. C. Turbine. Points Similarly Marked ⊖ × ● Correspond to Equal Steam Flows

Fig. 2 shows a study of possibilities, in connection with a Rice-Sargent engine which has been operated for some years at the Schenectady plant of the General Electric Co. This unit operates a 250 volt, direct current generator, and ordinarily runs with a load of about 1,200 kilowatts, condensing or non-condensing. The tests were accurately made by weighing condensed steam, the effect of vacuum being determined by holding the steam flow constant and changing the vacuum. The curves show the performance under condensing and non-condensing conditions, and also what could be accomplished with this engine in combination with a good low pressure turbine. The rates of gain here shown will seem extraordinary, but they are fairly representative of the possibilities in the average condensing engine plant.

It will be noted that the upper curve represents the engine operating non-condensing at 810 kw., with a steam consumption of 30.6 pounds per kilowatt. With the load increased to 1,065 kw., the steam consumption is 30.6 pounds per kilowatt; with the load increased to 1,265 kw., the steam consumption is 33.6 pounds; and it is evident that operating under these conditions, this last named output is practically the maximum capacity of the unit.

Now, when operating condensing with an output of 1,140 kw., the steam consumption is seen to be 22 pounds per kilowatt. At 1,320 kw., the steam consumption is 24.6 pounds, and when operating at 1,470 kw., the steam consumption is 28.8 pounds per kilowatt, and we have increased the maximum capacity of the unit from 1,265 to 1,470 kw.

Now, with the assistance of the low pressure turbine, vacuum conditions remaining the same, the steam consumption at 1,550 kw. is 15.6 pounds per kilowatt; at 2,020 kw., the steam consumption is 15.4 pounds; and at 2,500 kw. the steam consumption is 17 pounds per kilowatt, and we have increased the maximum output of the unit from 1,265 kw. non-condensing, or 1,470 kw. condensing, to 2,500 kilowatts.

You will also note that the amount of steam necessary to deliver 2,500 kilowatts with the engine and turbine working condensing, is practically the same as the amount required to produce 1,480 kw. from the engine alone, when operating condensing; and also practically the same as is required to deliver 1,265 kw. from the unit operating non-condensing. In other words, not a pound of additional fuel is required to produce these results, nor is any additional boiler investment made necessary.

If the information here given is carefully considered, it will be seen that very great improvements in efficiency and large increase in output can be accomplished at very small cost. The possible improvements are so great that no power user can afford to ignore them. The saving of fuel effected by such changes will very soon pay for them, even where increased capacity is not required.

Several installations of this description have already been made and the results obtained have been highly pleasing, not only to the purchasers, but likewise to the manufacturers; I will therefore attempt to describe one or two of these plants.

In 1905, the Philadelphia Rapid Transit Company installed an 800 kilowatt Curtis low pressure turbine at its power station on Thirteenth and Mt. Vernon Streets. This station was equipped with four 1,500 h.p. and one 2,200 h.p. Wetherill Corliss engines, which had always been operated non-condensing for the reason that cooling water was not available.

An Alberger condenser having 8,000 square feet of cooling surface, together with a cooling tower, was installed for use with the low pressure turbine.

The rotary pumps for circulating the cooling water are direct connected to a 120 horse-power interpole motor.

The average vacuum obtained is 28 inches.

The 1,500 horse-power engines are each direct connected to a generator which develops an average of about 2,000 amperes at 575 volts.

The turbine takes steam from the common exhaust main at a pressure of one pound above the atmosphere, and is provided with four wheels, each with a single row of buckets.

Exhaust steam from one engine, when delivering 2,000 amperes, is sufficient to deliver an output from the turbine of 1,300 amperes at 575 volts, with no increase of back pressure on the engine.

As about 150 amperes are required to operate the auxiliaries, the net gain from the turbine is from 1,000 to 1,200 amperes, or approximately 66⅔ per cent.

As the maximum gain possible resulting from the use of a condenser without the turbine would not exceed 25 per cent., it will at once be seen that the turbine produces a gain of 41⅔ per cent. over this arrangement.

The generator used in conjunction with this turbine is a direct-current machine, six poles, 1,200 revolutions. The unit is not fitted with a governor.

With the turbine taking steam at atmospheric pressure, with 2 inches absolute back pressure in the condenser, a water rate of 36 pounds per kilowatt at full load is guaranteed. The conductors from the turbine generator are connected by common bus bars with the leads from the engine driven units.

As before stated, this turbine is peculiarly simple, consisting of nothing but the wheels, shell and generator, without governor. It is prepared, therefore, to take at all times all the steam delivered to it from the reciprocating units, and the cycle of operation is somewhat as follows:

If the engine driven generators tend to take more than their proportion of load, the engine governors admit an additional volume of steam to produce the necessary energy; and the engines in turn deliver more steam to the turbine, speeding it up and thus increasing the voltage on the turbine driven generator. This causes this generator to take more load, thereby lessening the load on the engine driven generators, and making the regulation automatic.

As the load conditions were such as required a further increase in apparatus, a second 800 kw. Curtis low pressure turbine, with condenser and cooling tower, was installed early in 1906 under similar conditions to those of the first unit, taking steam from the same exhaust header and delivering current to the common bus bars.

All the auxiliaries required in connection with the turbines, condensers, and cooling towers, are motor driven, with the exception of two dry air pumps, one step bearing pump, and two discharge pumps, the exhaust from these being utilized for heating the feed water. The current required to operate the motors is about 14 per cent. of the output of the turbines.

The two turbines are operated about eighteen hours a day, and the only attention required is that demanded by the commutator and pumps.

The coal consumption at this station for all purposes for the first six months of 1905, before the turbines were installed, averaged 4.48 pounds per kilowatt-hour.

The coal consumption for all purposes for the first six months of 1906, after the turbines were installed, averaged 4.08 pounds per kilowatt-hour. showing a saving of 0.4 pounds of coal per kilowatt-hour.

As the total output of the station for the first six months of 1906 was 20,346,890 kilowatt-hours, this shows a saving of 4,069 tons of coal, or 8,138 tons for the year, which, when figured at $3 per ton, amounts to $24,414.00.

As these two turbines are not using all the exhaust from the five engines, it is plain to be seen that when their load requirements necessitate further increase, the installation of additional low pressure turbines capable of utilizing all the exhaust steam will cut the coal consumption down to at least three pounds per kilowatt-hour, and pay a handsome return on the investment.

Looking at this plant from a first cost point of view, the original steam equipment cost somewhere in the neighborhood of $100 per kilowatt, and to have increased their capacity on the original lines would have required an investment proportionately equal to the original investment. The low pressure turbines, with cooling towers, however, were installed at an expense of approximately $50 per kilowatt, and as the turbines were utilizing the energy in the steam previously unused, the fuel consumption was not increased a pound; or, in other words, considering one of the 1,500 kw. units operating with one of the 800 kw. low pressure turbines under the new arrangement, 2,300 kw. were made available with no more expense in regard to fuel and attendance than was previously necessary to deliver 1,500 kw.

During the year 1904, the engines were operated alone under normal conditions, with the following results:

Average kw. hours output per month,	2,475,000
" cost per kilowatt hour,	7.3 mills
" " of coal per kw. hour,	5.15 "
" pounds " " " "	4.6 "

These conditions prevailed until January, 1905, when the first 800 kw. low pressure turbine was put in operation. From January, 1905, to January, 1906, the results were as follows:

Average kw. hours output per month,	2,500,000
" cost per kilowatt hour,	6.9 mills
" " of coal per kw. hour,	4.97 "
" pounds " " " "	4.47 "

This shows that the addition of this low pressure turbine, amounting to an increase in station capacity of a little over 10 per cent., and delivering an increased average amount of power of 10 per cent., cut down the coal consumption by 210,000 pounds per month, or 105 short tons; or, in other words, an expenditure of approximately $40,000 enabled the purchaser to deliver 25,000 kw. additional per month, at a profit, and at the same time save 105 tons of coal. Stated differently, the plant actually delivered 10 per cent. more power with approximately 2 per cent. less fuel, incident to the installation of the first low pressure turbine.

In January, 1906, the second 800 kilowatt low pressure turbine was put into service. Let us examine the result and again draw comparisons. We find the following conditions for the year, January, 1906 to January, 1907:

Average kw. hours output per month,	2,957,500
" cost per kilowatt hour,	6.03 mills
" " of coal per kw. hour,	4.5 "
" pounds " " " "	4.08 "

It is seen that during the year, from 1906 to 1907, the turbines averaged to carry 16.8 per cent. of the load.

Comparing the conditions during the year 1906, with the two turbines in operation carrying but 16.8 per cent. of the total load, with the year 1904 before the turbines were installed, we find that the station delivered an increased average amount of power to the extent of 19.5 per cent., or 482,500 kilowatt hours per month; that the total cost of the station output for the year 1904 was $216,810, while the total cost for the year 1906, with engines and turbines delivering 5,790,000 kw. hrs. more than for 1904, was $214,004.70; or, in other words, that it cost $2,805.30 per year less to deliver 19.5 per cent. more energy incident to the low pressure turbine installations.

For the benefit of those who are inclined to feel that, while the advantages of the low pressure turbine may be all that are claimed for it when used in conjunction with a non-condensing engine, or with a condensing engine which gives poor economy, but are inclined to be extremely skeptical as regards its usefulness when used in conjunction with a first-class compound condensing engine which is producing exceptional results, I would like to set forth the results of an investigation and recommendations which I recently had occasion to make in one of the most economical steam-electric power plants in New England. The general arrangement of this plant is as follows:

The boiler floor level is considerably below the engine floor level; the basement is still lower. This arrangement leaves nearly 14 feet clear height in the basement, and gives excellent space for the primary heaters, air pumps, exciter engine, and the rest of the machinery there installed. Babcock & Wilcox boilers, each having 3,964 square feet of heating surface, 67.6 square feet of grate surface, and 125 square feet of superheater coils, are installed. The feed pumps are Blake duplex outside-packed plunger pumps, driven by tandem compound steam cylinders.

The feed passes through a main heater in the main engine exhaust pipe, through a closed auxiliary heater where it receives heat from the feed pumps and air pump exhausts, and then through a Green economizer to the boiler. The condensers are Blake vertical twin jet condensers.

The cooling water is taken direct from a river flowing by the plant.

The two engines are McIntosh & Seymour vertical, two-cylinder, cross-compound 18 in. and 38 in. by 42 in., each engine developing 760 indicated horsepower at 0.24 cut-off, with 135 pounds initial steam pressure and 26 inches effective vacuum. Each engine is direct-connected to a 600 kw., 60 cycle alternating current generator, operating at a speed of 120 revolutions per minute.

Each high pressure cylinder is jacketed on the barrel, and both heads and the jackets are piped in series. The steam enters the jacket at the top head, passes into the barrel jacket, goes to the jacket on the lower head and then to the reheater coils. As there is no separate steam supply to the reheater coils, nor any separate drain from the high pressure jackets, it is not possible to use either jackets or reheater alone.

The receiver is a large cylindrical drum located at the back of the engine and close to the cylinders.

The reheater consists of one or more coils of pipe in the receiver. The low-pressure cylinder is unjacketed.

I have gone into the principal details of this plant that you may appreciate the fact that the highest economy was sought in its design, and that the desired results were accomplished is evidenced by the fact that, when tested by Lionel S. Marks, Assistant Professor of Mechanical Engineering at Harvard University, engine No. 1, carrying a load of 485 kw., and operating at 139.5 pounds pressure at the throttle, with steam superheated 75° Fah., and exhausting into a vacuum of 26.27 inches, produced a water rate at the switchboard of 19.52 pounds of steam per kilowatt.

Engine No. 2, carrying a load of 577 kw., and operating at 133 pounds pressure at the throttle, superheated 55.5° Fah., and exhausting into a 26-inch vacuum, produced a water rate of 19.51 pounds of steam per kilowatt.

The condensers previously mentioned were capable of maintaining a 28-inch vacuum under full load conditions, but as the gains made by the engines with this vacuum were not commensurate with the expense of maintaining it, a vacuum between 26 and 27 inches was ordinarily kept up.

The location of the condensers with relation to the engines was such as to offer ample floor space for the installation of low pressure turbines between the exhaust from the low pressure cylinders and the condenser, by simply taking out a section of the exhaust and introducing the turbine.

The load conditions in this plant were such that the daily output was from 750 to 900 kw. continuously, and required the running of both units partially loaded day in and day out; under these conditions they operated at an average water rate of 27 pounds per kilowatt.

A careful investigation of these units developed the fact that each was capable of developing from 15 to 20 per cent. over load when exhausting to atmosphere, at a water rate of 25 pounds per kilowatt at full load, and 27.5 pounds at 10 per cent. over load.

Therefore, operating one engine non-condensing at 575 kw., at a water rate of 27.5 pounds, it would deliver 15,812 pounds of steam per hour.

The water rate of a 500 kw., 1,800 r.p.m. turbine, supplied with this steam at atmospheric pressure and exhausting into a 28-inch vacuum (which this condenser is capable of maintaining), would be 33 pounds per kilowatt.

It will be readily seen that the engine will deliver enough steam when operating at 575 kw., to obtain from the turbine 480 kw., or a total of 1,055 kw. from the combined unit, at a water rate of 15 pounds per kilowatt.

While they are now generating 900 kw., with 27 pounds of steam per kilowatt hour, thus using 24,300 pounds of steam per hour, an investment of less than $20,000, will reduce the steam consumption to 17 pounds per kilowatt hour, requiring only 15,300 pounds of steam per hour.

Figuring on an evaporation of 10 pounds of water per pound of coal, this would represent, for 300 days of 10 hours each, a saving of 1,350 short tons, which, at $3.00 per ton, would yield a yearly saving of $4,050. This would pay for the turbine complete in five and one-half years, with 11 per cent. interest on the investment.

By piping the exhaust of both engines to the turbine and connecting the latter through suitable valves with both condensers, the turbine can be used with either engine, thus making the other a spare.

Through the courtesy of a large electric light company, I am fortunate in being able to present for your consideration the report of Prof. Ira N. Hollis on the result of his investigations on this subject, as follows:

"In compliance with your request, I submit the following report on the economic possibilities of a steam turbine in the ——— Electric Light Station.

"There are at present in the station two 500 kw. steam engines, one 1,500 kw. steam engine, and one 2,000 kw. steam engine, all of the McIntosh & Seymour type. They are designed to run with a possible overload of 50 per cent. for a short time. There is, therefore, a possible normal output of 4,500 kilowatts, or for a short time, of 6,750 kilowatts. steam is taken from the boilers at a pressure of about 145 pounds, and exhausts into ordinary jet condensers after having passed through a closed heater. The condensed steam and the circulating water are removed from the condenser by the ordinary bucket air pump. The proposition, as I understand it, would be to run the McIntosh & Seymour engines on 15 pounds back pressure, and to utilize this back pressure in driving a low-pressure turbine. Inasmuch as the steam engines now in use in the station are compound, this would amount to making of each engine a triple expansion engine whose third cylinder would be replaced by a turbine. The combination is an entirely practical one and would not present mechanical difficulties either in building or in operation.

"It has been stated that there is as much available energy in the steam below 15 pounds as between 145 and 15, or, putting it more briefly, there is as much available energy in steam below the atmospheric pressure as above, in the ordinary stations. This is probably true, although not at once apparent to those who have no technical training in the use of steam. It is not so difficult to understand, however, when one considers that the energy of steam is represented by the product of the pressure and the volume (not by pressure alone). When the steam is at high pressure, the specific volume is necessarily much smaller than at low pressure. Roughly speaking, the volume may be said to be inversely proportional to the pressure. This being true, one can see that it would be entirely possible for the volume multiplied by the pressure above the atmosphere to be practically the same as the volume multiplied by the pressure below the atmosphere.

"In order to determine with fair accuracy the possible economy with the combination suggested above, I ran one of the 500 kw.

engines under three back pressures: first, with as great a vacuum as it was possible to obtain by speeding up the air pump; second, with a very moderate vacuum, and third, on the atmosphere. It was not possible to weigh the feed water used under these different conditions. There is enough data available from the test made several years ago in connection with the indicator cards taken in the above test to determine within a very small per cent. of error the amount of steam used per indicated horsepower per hour. This was done, and a combined card made of the third case, in order to figure out the amount of energy available for the steam turbine.

"During the run the exhaust steam from the air pump and feed pump was carefully weighed, in order to determine the expenditure for the auxiliaries. While the main engine was on the atmospheric pressure, of course there was no exhaust of steam from the air pump. A table has been made out to show the result. It will be noticed that with the greatest vacuum—namely, 27 inches—the indicated horsepower developed by the engine was 803; with the vacuum of 23.3 inches, the indicated horsepower was 836, and with atmospheric exhaust, amounting to 16 pounds back pressure, it was 1,010. These figures may seem paradoxical, inasmuch as one naturally supposes that less power is developed by an engine when exhausting on the atmosphere, but in this case the cut-off naturally responded to the greater demand for steam, and consequently the power was increased in proportion to the demand at the switchboard. Furthermore, I purposely had the load increased during the atmospheric exhaust, in order to show that it was entirely possible to run the engine with an overload. The table which is here added is otherwise sufficiently explanatory. It will be noticed in the last line that there is no gain by increasing the vacuum beyond 23 or 24 inches with the present arrangement in the station, inasmuch as the amount of steam used by the auxiliaries offsets the gain in the engine. The steam per kilowatt is set down as 22.26 with 27 inches; 22.24 with 23.30 inches; and 32.60 with atmospheric exhaust. This includes not only the steam expended on the main engine, but also the steam used on the auxiliaries, and is practically the total outlay of steam per kilowat for the station, as represented in the three conditions attached.

TABLE

Back pressure (pounds per square inch absolute),	1.5	3.3	16
Indicated horsepower,	803	836	1,001
Kilowatt,	540	563	673
Pounds steam per indicated horse power,	13.21	14.10	21.58
Pounds steam per kilowatt,	19.64	20.96	32.07
Pounds steam per indicated horse power, including air and feed pump,	14.97	14.96	21.94
Pounds steam per kilowatt, including air and feed pump,	22.26	22.24	32.60

"The greatest amount of power thus obtained from one of the 500-kilowatt engines was 1,001 indicated horsepower, or 673 kilowatts at the switchboard. This was done without readjustment of valves for smooth running. During the test of the engine there was a great deal of noise in the bearings and in the cylinder of the low-pressure engine. All this could have been removed by taking ample time to readjust the gear for atmosphere exhaust, but it did not seem advisable at this time to make such adjustments, as the engine might have been laid up for several days. The tests, therefore, represent only the possible power with a close approximation to the amount of steam expended per indicated horsepower or per kilowatt hour.

"It will be seen, therefore, that 673 kilowatts are obtained on 32.07 pounds of steam per kilowatt hour, excluding the auxiliaries. A combined card was made, in order to calculate with some accuracy the amount of power available for a low-pressure steam turbine in case the steam were turned into the nozzles of such a turbine instead of being thrown away into the atmosphere. This power would, of course, be obtained without further expenditure of steam. It amounts to 1,069 horsepower, to be added to the 1,001 developed in the cylinders. The output with a steam turbine would, therefore, be 2,070 indicated horsepower, or 1,392 kilowatts, as against the normal output of 500 kilowatts, for which the engine was designed. A very great expansion of power is, therefore, at once apparent, so that there would be no question of the advantage of the turbine for the purpose of expanding the power with the present machines in the station. This increase is simply for one engine, and would represent for the whole station the same proportionate increase on 4,500 kilowatts. The total output of the station could there-

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fully. It is difficult at the best to maintain a vacuum of 28 to 29 inches reliably. In some stations where large power is developed it has been done, but in most small stations I have seen, the vacuum has usually fallen below 28 inches. Still, I do not think that this company ought to be restrained from putting in a low-pressure turbine on account of the fear of the mechanical difficulties connected with the vacuum. I should not hesitate a moment on that account. The cost in steam of producing a vacuum would probably be less than the amount used in the above calculation.

"The saving represented by the preceding figures is, on the whole, based on a conservative estimate of the power available in the turbine, and I think it would be fully realized with a vacuum at 28.5 inches. I understand that the General Electric Company are prepared to guarantee a steam consumption of about 15 pounds per kilowatt per hour. My own opinion is that, if the guarantees can be realized without trouble with the auxiliaries, no modern compound steam-engine plant will be complete without a low-pressure turbine. In fact, no electric-lighting company could afford to run the compound engine alone.

"The company we have been considering has recently installed a 2,000-kilowatt compound engine, for which there is no business at present. It represents a reserve for use in case other engines give out. At the same time it must have a bearing upon the expenditure of $25,000 for additional machinery. It seems to me that the saving represented above would enable the company to reduce the price of current to consumers and possibly to increase the business very materially. This, in my opinion, forms the basis of judgment on an immediate expenditure for the turbine. In case there were demand for more current than the station can now supply, I should unhesitatingly recommend the low-pressure turbine as a means of obtaining it. As the case stands, I think there is certainly a prospect of sufficient gain to make it an important consideration for the company. I have made no attempt to get prices on the turbine or on the auxiliary machinery, but have confined myself to the possibility of saving, under the supposition that all expenditures, except those for coal, would remain approximately the same. As to the method of installation, in case the company should favor the early addition of a steam turbine, my recommendation would be to put in a 1,200 kilowatt turbine to use the exhaust steam from either or both of the two 500 kilowatt engines. The type of condensing apparatus can be determined by a further study of the subject after the company has decided definitely the general question. The location of all the new machinery can likewise be definitely fixed. There is plenty of room in this station, although it might be necessary to rearrange some of the smaller machines.

"Attention may be called to the fact that, with the exhaust turbine, one 500 kilowatt engine and the turbine would take care of the ordinary daily load, and that two 500 kilowatt engines with the turbine would provide for the maximum load. There would probably be some saving due to the reduction of the number of boilers required for the load. In most cases, one boiler less would be demanded, and the loss from radiation and leakage would thus be materially reduced.

"I may add in conclusion that I think the company is acting wisely in taking this question up for consideration."

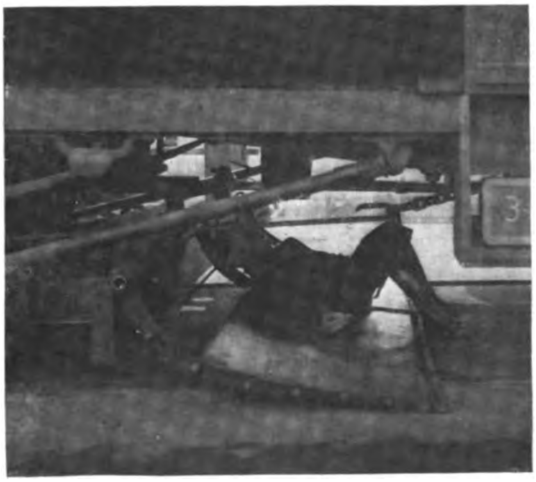
Immense benefit can be derived from the use of low pressure turbines in mechanically operated manufacturing plants. Take for instance a mill or other manufacturing establishment mechanically operated by means of belts or ropes, where an increase is desirable, and either due to the shape or position of land available, this addition cannot be economically or satisfactorily reached by belting and shafting; the low pressure turbine offers an ideal solution of the problem, permitting the electrical operation of the sections which are awkward to reach mechanically.

In closing, permit me to caution you not to entertain a wrong impression of the idea intended to be conveyed; that is, I feel that the turbine will more economically utilize the steam energy, both above and below the atmospheric line than the reciprocating engine, and therefore is entitled to first consideration in a new installation; but where an increase is necessary to an existing reciprocating plant, the low pressure turbine can oftentimes be used to better advantage than any other piece of apparatus, without entailing increase in boiler plant or buildings proportionate to the increase in capacity, and in many cases without any increase of the items mentioned.

CAR FENDER AND WHEEL GUARD TESTS AT SCHENECTADY

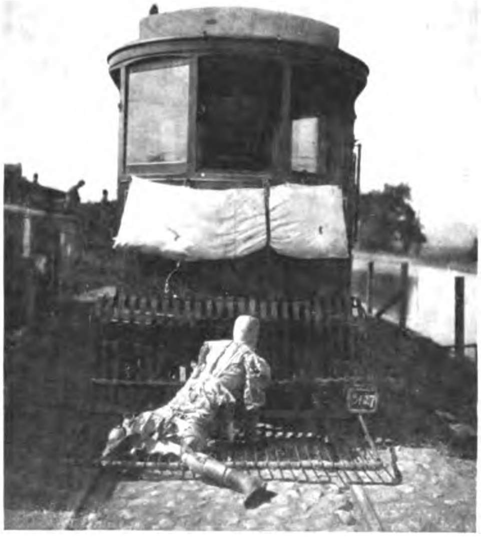
The car fender and wheel guard tests which were instituted by the New York State Public Service Commission of the First District, and which have recently been completed on the experimental track of the General Electric Company at Schenectady, have been by far the most elaborate and complete tests of the kind ever inaugurated. No trouble was spared in the endeavor to approach as closely as possible the conditions that the devices would have to meet in actual service, and to this end, two sections of roadbed were especially prepared —one with cobblestones, and one with tar paper covered with sand to simulate asphalt.

The speeds at which the cars were run were 15 miles per hour, and 6 miles per hour; the higher speed being about that at which cars are operated in the outlying districts of New York City; while the lesser rate is approximately the speed at which cars must be run throughout all that section of the city extending from Forty-second street to the Battery.



Automatic Wheel Guard Picking Up Boy Dummy

The dummies were constructed to represent the human form very closely, being provided with jointed members, weighted in the proper manner, and even clothed. This was a radical departure from former tests and approximated actual conditions far more closely than has been done heretofore. To mention one point: the dummies being able to stand of themselves, dropped when struck in much the same way as would a person, producing a falling effect impossible to secure with the dummies that have been used in earlier tests and that required to be supported by a plank or tripod.



Drop Fender Picking Up a 120 lb. Dummy

The devices tested can be divided into three general classes; the first of these being the projecting, automatic drop fender, usually operated by some form of trip which extends beyond the fender, and which, when coming in contact with any object, causes the fender to drop into position.

The second class is also of the drop type, but is not automatic, being controlled and operated by the motorman. This kind has been tried for years and is efficient when dropped. Its successful operation depends upon the ability of the motorman to meet an emergency.

The third variety is the wheel guard type and consists of a device usually placed under the car, which, as its name implies, picks up the victim of an accident before the wheels are reached. Experience has shown that people are rarely killed by the blow from a fender; when fatalities have occurred, it has generally been found that the person struck has been thrown ahead on the track and run over by the wheels. This being the case, the wheel guard forms an efficient means of preventing such casualties.

The object of the test has been to determine what fenders or wheel guards are suitable for use in New York City. In addition to picking up the victim of an accident without fail, the device should not be excessively expensive to maintain; should be sufficiently strong to withstand the operating conditions, and must be reliable in case of emergency.

A. W. McLimont

Electrical Engineer
Public Service Commission
First District, New York.

The fender test conducted at Schenectady under the direction of the Public Service Commission of the First District, has been of exceptional value by reason of the effort that has been made to reproduce as nearly as possible the actual condition and action of the fenders that would occur in ordinary service. The unexpected attitude assumed by the dummies after being struck, and the action of the fenders under the different positions of the dummies, correspond very closely with many of the known instances of accidents to human beings.

The noticeable difference in the effectiveness of the different types and designs of fenders under the conditions of the test, brought out more forcibly than could have been done in any other way the more important features essential to affording the greatest degree of safety to the public.

Tests of this character are unquestionably of great value in establishing as matters of fact, what would otherwise be questions of opinion. Practical tests of this general character on whatever class of apparatus should result in the increased safety and comfort of the traveling public.

W. B. Potter.

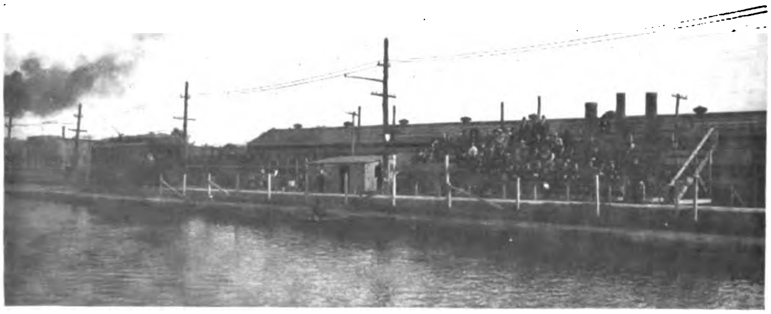
Chief Engineer
Railway Engineering Department
General Electric Company.

The particular feature that has rendered the fender test of special interest has been the elaborate attempt to simulate as closely as possible the actual conditions that occur in service. Of course, there is a great difference between striking an inanimate object and a living human being, but this was an inherent limitation that could not be overcome. The preparation of the roadbed to reproduce the condition of asphalt and cobblestone paving, and the use of jointed dummies that would stand erect without support and were of the proper height and weight, etc., approximated the actual condition as closely as possible.

The equipment for properly carrying on the tests was very complete. The General Electric Company furnishing an interurban, and also a single truck car for the purpose, and erecting an observation stand, and several buildings for use as offices, dummy repair shed, photographic house, etc. This last was made necessary by reason of the fact that the result of each separate test was recorded photographically, the official photographer, Mr. P. P. Pullis, taking in all about one thousand exposures.

The Public Service Commission of the First District of New York, under the direction of which the tests were made, consists of the following members: William R. Willcox, chairman; William McCarroll; Edward M. Bassett; Milo R. Maltbie; John E. Eustes.

The Committee having direct charge of the test was composed of D. L. Turner (Chief of Transit Inspection Bureau), G. F. Daggett (Chief of Bureau of Accidents), and A. W. McLimont (Electrical Engineer for the Commission), chairman.



Experimental Track and Grand Stand

AUTOMATIC STARTERS FOR POLYPHASE INDUCTION MOTORS

By C. D. Knight

There has been for sometime a demand for reliable devices to automatically operate both the slip ring and squirrel cage type of induction motors when used for distant control, or in connection with pump service and air compressors. The two devices herein described fulfill both these requirements.

Fig. 1 shows an automatic compensator for a 100 h.p., 220 volt, 60 cycle, 3-phase, Form "K" induction motor. The apparatus consists of a panel on which are mounted eight A.C. contactors and a time limit relay, the starting compensator coils being mounted in the rear. To start the motor, five of the contactors and the time limit relay are energized through either a pressure governor, float switch, or an auxiliary push button switch. This connects both of the compensator coils with the line, and the motor with the coils, doing automatically that which is accomplished by a hand operated compensator when thrown into the starting position, as described by Mr. Gehrkens in the Review for March, 1907.

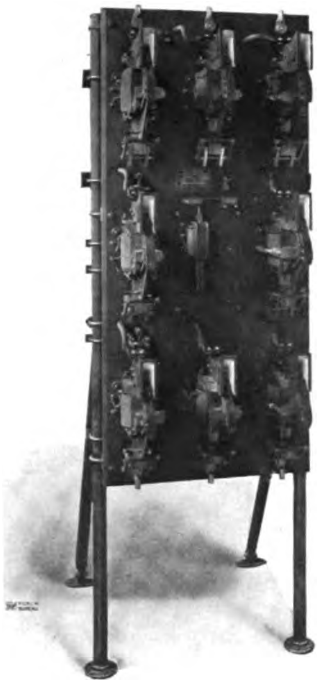


Fig. 1. Automatic Compensator for 100 hp., 220 Volt, Form K, Induction Motor

The time limit relay, as shown in the center of the panel, consists of an A.C. solenoid, the action of which is governed by an air dashpot so regulated as to give any desired acceleration of the motor, up to 60 seconds. This relay operates a small two throw switch directly above it. As previously stated, this relay is energized at the same time as is the contactor. When its plunger reaches the end of its stroke, it quickly opens the coil circuits of the five contactors and closes the remaining three. This operation disconnects the motor from the compensator and throws it directly across the line to its final running position. When it is desired to stop the motor, the auxiliary switch, previously mentioned, is opened, thereby de-energizing the three lower contactors and opening the motor circuit.

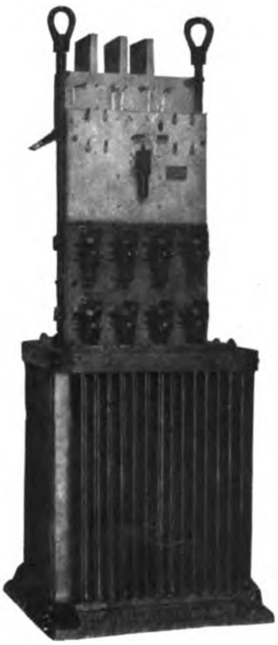


Fig. 2. Compensator for High Voltage Motors. Open

The apparatus is so interlocked that it is impossible to have both starting and running contactors energized at the same time. It is impossible to throw the motor directly across the line without automatically performing a cycle of operation, as described.

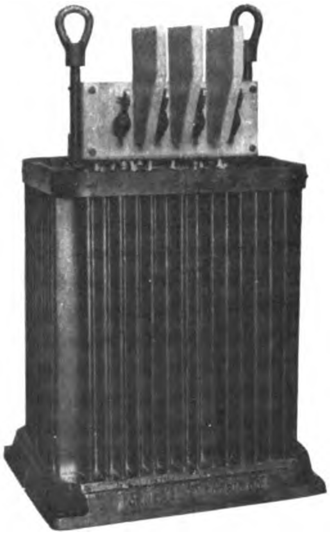


Fig. 3. High Voltage Compensator. Closed

With the use of contactors, the no-voltage release features are secured both in starting and running. An additional overload device can also be supplied, which will open-circuit the contactor coils and disconnect the motor from the line.

For the high potential motors, a compensator similar to that shown in Fig. 2, open, and Fig. 3, closed, is supplied, the rating of which is 85 h.p., 3-phase, 2080 volts. The same type of alternating current contactor is used here as in the previous case, with the exception that it is submerged in oil. One cut shows the compensator with the parts removed for inspection, and the other as completed, ready for operation. In cases where high potential compensators are used, it is necessary to have a small transformer to reduce the contactor coil energizing voltage to 220 or 440.

Fig. 4 shows an automatic starter for Form "M," or slip ring type induction motors. In starting this type of motor, the resistance is inserted in the secondary winding, being gradually cut out, and finally short circuited, as the motor comes up to speed.

The apparatus consists of a panel at the top of which are mounted three A.C. contactors, and below these a three phase ratchet driven arm operating over three sets of resistance contacts, the resistance being mounted and connected on the back of the panel. The cycle of operation is as follows:

By means of an outside auxiliary switch, the ratchet solenoid is energized. This immediately moves the three phase arm to the full resistance position. At this point the three main line contactors are closed and the motor starts to accelerate. The arm continues to travel automatically, cutting out resistance until the "all out" resistance point is reached and the secondary of the motor is short circuited. The apparatus is so interlocked that it is impossible to close the main line contactors with any part of the starting resistance cut out.

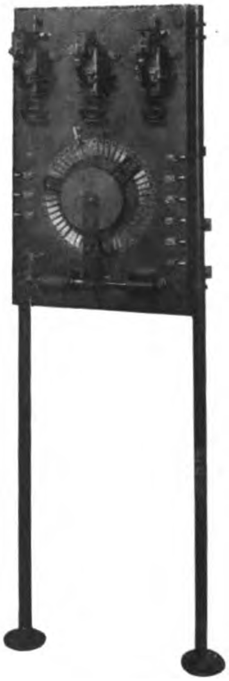


Fig. 4. Automatic Starter for Form M Induction Motor

In cases where the current controlled is exceedingly heavy, the three phase dial switch is used as an automatic master controller for energizing contactors, these in turn cutting out steps of resistance in the motor secondary.

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arranged so that they can be easily renewed by the average station man, without the necessity for dismantling the circuit breaker.

The tripping mechanism is one of the most important features of the automatic circuit breaker, and the simpler its design the greater its reliability, and the use of a complicated arrangement of levers, rollers, springs, etc., should be carefully avoided.

No other form of operating mechanism for circuit breakers is as efficient as the toggle. With this arrangement it is possible to obtain the maximum amount of power with the minimum amount of effort when the contact brush is being put under full pressure; and it is also possible to hold the circuit breaker in the closed position with the minimum pressure on the retaining latch, thus making the amount of power required to trip the breaker well within the limits of a reasonable sized tripping magnet. In this connection it should be noted that it is most desirable to have a design which will permit of the circuit breaker being removed from the base or panel upon which it was originally assembled and mounted on another, without in any way upsetting the adjustment of the calibrating device of the tripping magnet.

Now, just a word with reference to the mounting of circuit breakers. An open arc circuit breaker, which is expected to open any considerable amount of current, should be mounted at the top of the switchboard panel, or at a height equivalent to this, if used in some other way. This location will insure, as far as possible, the flash from the arc being out of the usual range of vision of the operator, and will prevent damage to instruments and other apparatus mounted with it. This arrangement will also avoid the possibility of the operator being burned when operating other apparatus at the time the circuit breaker opens.

While there are other points in circuit breaker design which should be carefully considered, the writer has only attempted to point out some of the more important ones which do not seem to be generally understood, or at least are often overlooked.

NOTES

Mr. W. J. Wooldridge requests us to state that the article appearing in the OCTOBER REVIEW on "The Multiple Operation of Transformers" was prepared by Mr. R. W. Sorensen and should have been credited to him instead of Mr. Wooldridge.

* * *

The following publications have recently been issued by the Publication Bureau of the General Electric Company:

3685	Folder. Improvements in Edison Lamps.
3687	Pamphlet. Transformer Steel.
3694	List of Sales of Railway Rotary Converters.
3697	Blotter G-I Flame Arc Lamps.
3698	Blotter G-I Flame Arc Lamps.
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4617	Direct Connected Generating Sets.
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4621	Multiple Luminous Arc Lamps.
4622	Polyphase Maximum Watt Demand Indicator, Type W.
4623	Parts of G-I Types L-7 and L-8 Enclosed Arc Lamps.
4624	Parts of Form 4 Weatherproof Arc Lamp Hanger and Cut-out.
4626	G.E. Repair Shops.
5186	Edison Incandescent Lamps.
5187	White Core-30 per cent. Para.
5188	National Electric Code Standard.
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The high efficiency of tungsten lamps is best realized after they are installed, but a practical demonstration of their economy is

A Convincing Argument

The General Electric Company's new Lamp Testing Watt Indicator is designed for just this service. This pocket size instrument indicates the exact watts consumed by the lamp. To use the instrument, the connecting plug is screwed into the lamp socket, the lamp to be tested being inserted into the socket in the bottom of the instrument.

For 100 to 120 volt circuits
Capacity 1½ amperes—125 watts

1920

Low Pressure Curtis Steam Turbines
use steam otherwise wasted in exhaust

The exhaust steam discarded as useless by reciprocating engines continues to do useful work in these turbines from exhaust pressure down to any available vacuum

30% to 100%
is added to the station output
without additional fuel

Low Pressure Curtis Steam Turbine Generators are available in standard sizes from 300 kilowatts up. They possess the same characteristics of operation that have made the Curtis Steam Turbine the peer of prime movers

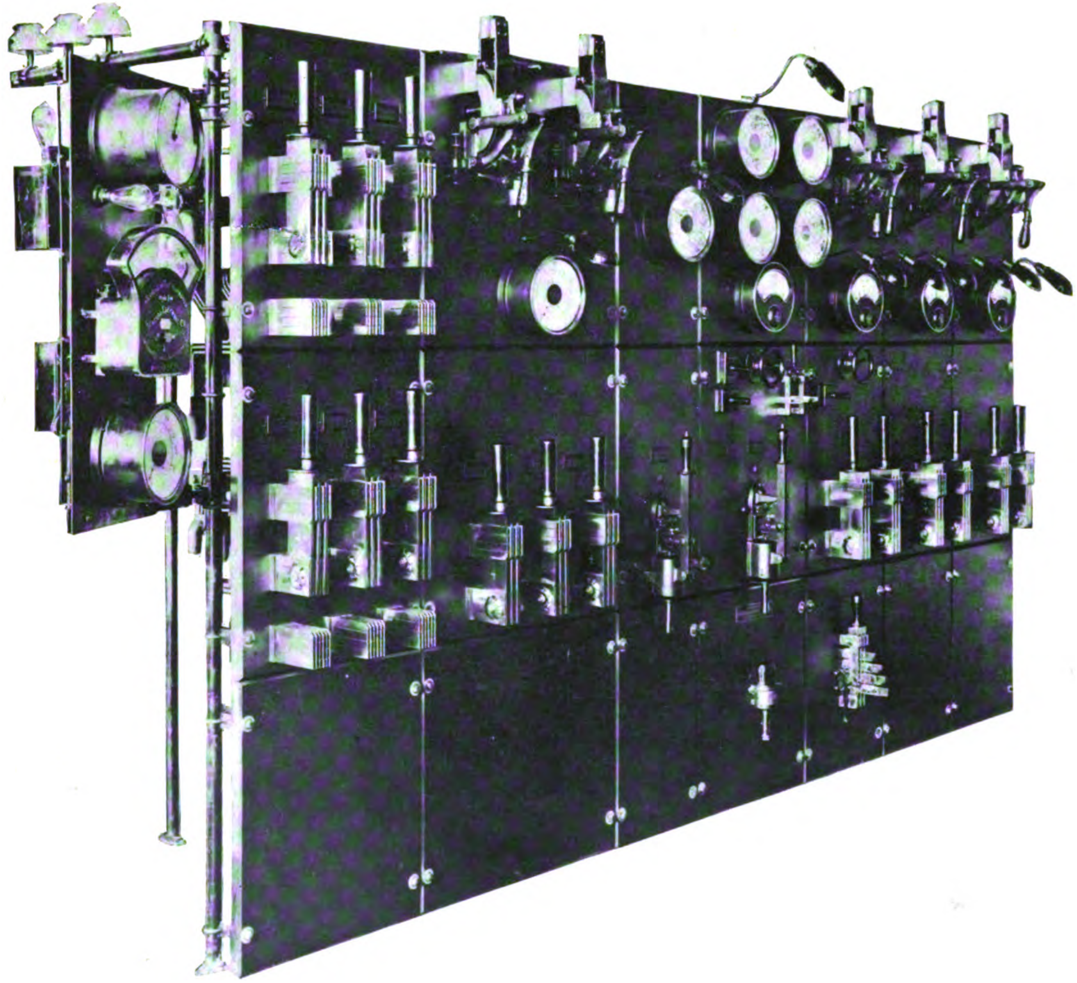
1918

GENERAL ELECTRIC REVIEW

VOL. XI, No. 6

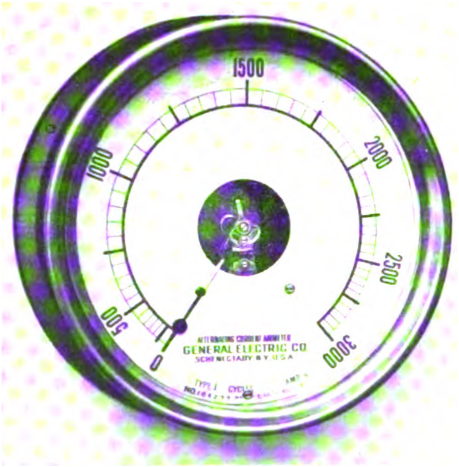
PUBLISHED MONTHLY BY
GENERAL ELECTRIC COMPANY'S PUBLICATION BUREAU
SCHENECTADY, NEW YORK

DECEMBER, 1908



A.C.-D.C. SWITCHBOARD
(See page 264)

Alternating Current Instruments
Ammeters and Voltmeters
Type I



These switchboard instruments are constructed on the induction principle and are particularly suited for certain classes of service because of the exceptionally long and legible scales.

Indications are perfectly dead-beat.

Instruments are protected from the influence of stray fields and are compensated for temperature and freqency variations.

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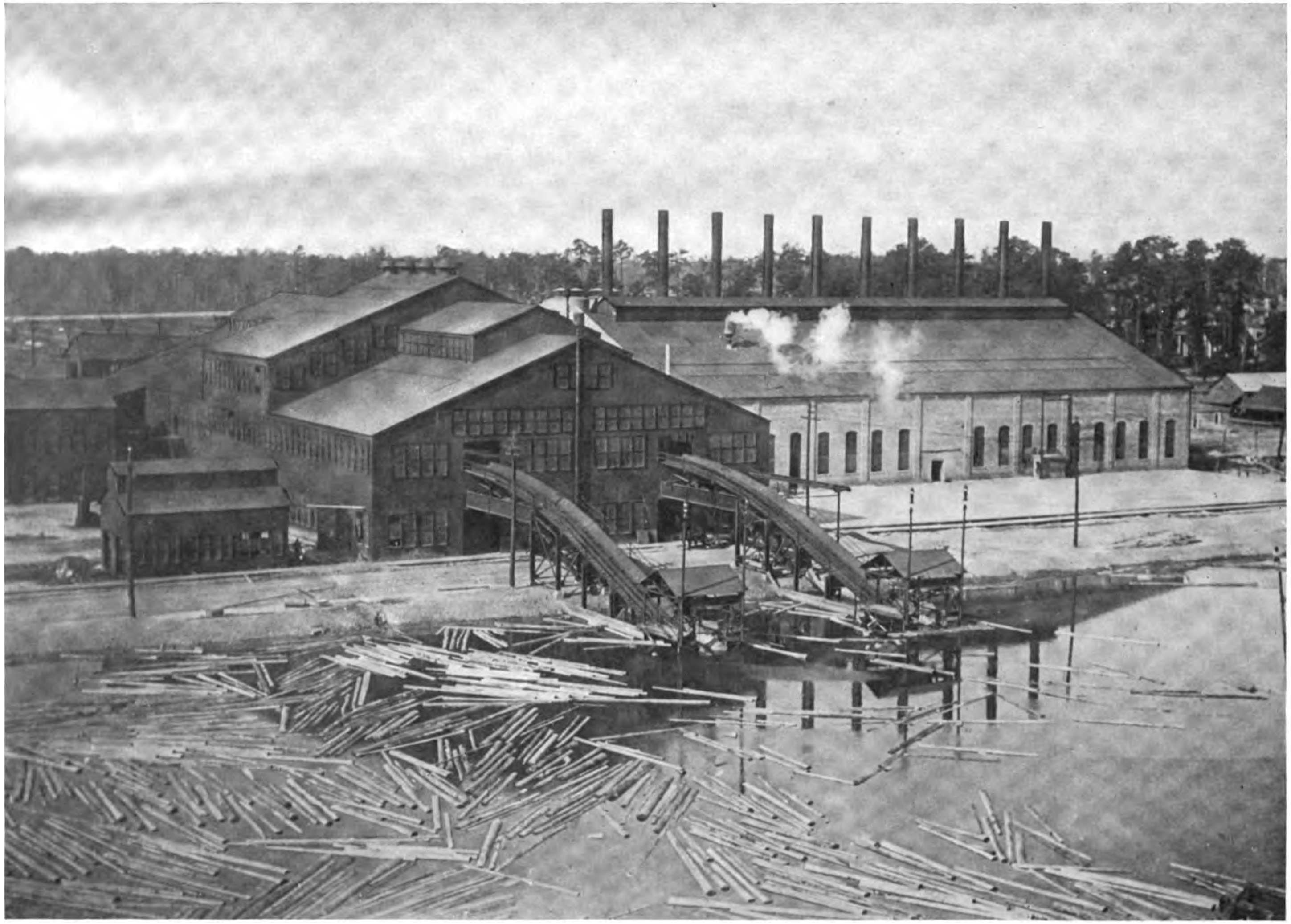


General View of Saw Mill, Great Southern Lumber Company, Bogalusa, La., Showing Part of Mill Pond, Log Haul-ups, Lath Mill on the Left and Power House on the Right.

(See page 254)

GENERAL ELECTRIC REVIEW

THE NEW INCANDESCENT LAMPS*

BY FRANCIS W. WILLCOX

Central station interests have great cause for rejoicing in that the incandescent lamp has qualified by improvements in efficiency to rank with the foremost of electric illuminants. Ideal in all other respects this attribute of efficiency now definitely establishes the incandescent lamp as supreme for a large majority of applications in the lighting field.

It is as rare as it is fortunate that the evolution of an art or science should culminate in such a simple piece of apparatus; as a finality in type of device it leaves little to be desired, except, of course, still further gains in efficiency.

Chief among the many benefits and advantages bestowed by the general adoption of the incandescent lamp are the simplification of service and the saving in investment cost and antiquation. The reduction of the investment that is required means a tremendous saving to central stations, as can be readily and fully appreciated by considering what has been and is being written off today to cover arc and glower lamps.

The improvements and developments in the incandescent lamp have been so numerous and extensive in the past two to three years, that it is time for central station companies to take stock of the gains that have been secured, in order that they may determine the best course to pursue in the adoption of the new and the elimination of the old lamps.

The incandescent lamp manufacturer formerly had but one kind of lamp to supply, *viz.*, the carbon filament, while now there are four varieties produced: carbon, GEM, tantalum and tungsten. Various classes and types of lamps are produced in each of these four kinds, resulting in a great multiplication of varieties of lamps, many of which should be discontinued as obsolete and supplanted by the new and improved types.

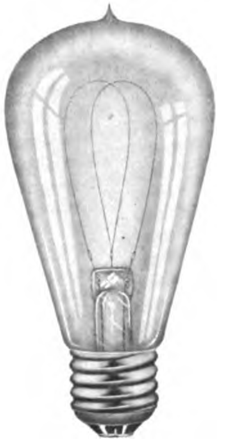
The GEM or Metallized Filament

The GEM, or metallized filament, as is well known, is simply an improved carbon filament, which, by special treatment in an electric furnace, is reduced to such a refractory condition that it will operate at 20 per cent. higher efficiency with the same life and candle-power performances. Such are the advantages of the carbon filament in durability, high resistance, low cost, etc., that any improvement therein has a far reaching value, and the GEM filament therefore is of great practical worth.

The GEM filament marks a very important advance over the carbon one, giving as it does in one step an improvement equal to that between the old 4 watt per candle lamp and the 3.1 watts per c-p. lamp, which latter advance took some fifteen years of hard work to accomplish. The GEM filament has been under development now for over three years and on the market for over two years. With allowance for some variable and unsatisfactory results which occur with any new development, the lamp has made an excellent record since its introduction, particularly in the high candle-power sizes used with Holophane reflectors as lighting units. As is well known, the GEM lamps are supplied in the following sizes: 50 watts, 80 watts, 100 watts, 125 watts, 187 watts, and 250 watts.

**Paper presented at the Annual Convention of the Iowa State Electrical Association at Des Moines, Iowa, May, 1908. As presented, one section of this paper was devoted to the tantalum lamp; this matter has been omitted from the present article as it has already appeared in the June issue of the* REVIEW.

The high-candle power lighting units, employing GEM lamps of 100 watts and over in scientific combination with Holophane reflectors, have been a great success and are widely used for general illumination of interiors. They supply a desirable form of electric lighting unit, a simple and inexpensive type of device which every central station desires and appreciates.



50 Watt GEM Lamp

The first cost of the complete unit runs below $10.00 per kilowatt as compared to $40.00 or more per kilowatt for glower and similar lamps. These units have economically replaced many other illuminants, and have been shown by numerous practical illumination tests to give better efficiency than the glower ones. These units follow simple rules for definite illuminating results, thus enabling any one to employ them without any complicated calculations. The tungsten lamp is adapted for use along the same lines as the GEM lamps, and will fit in the same reflectors as have been supplied for the latter; thus these incandescent units will be continued with the new lamps without any change in installation and without added expense other than the difference in lamp renewal cost. As a result of the improvement secured the GEM lamps have definitely replaced several sizes of carbon lamps which are now obsolete, as follows:

The 250 watt GEM lamp has replaced the 100 c-p. carbon lamp now discontinued.

The 125 watt GEM lamp has replaced the 50 c-p. carbon lamp now discontinued.

Along the same lines the 100 watt GEM lamp has largely taken the place of, and should entirely replace the 32 c-p. carbon lamp, which should be obsolete.

The life and candle-power performance of the GEM 100 watt lamp has been most excellent during the past year, averaging close to 550 hours at top voltage at about 2.55 watts per candle. This gives the following table of values and comparisons:

TABLE I

Voltage Range	GEM—100 WATT			CARBON—32 C-P	
	Watts per Candle	Mean Horizontal C-P.	Useful Life	Watts per Candle	Useful Life
Top or 1st Voltage...	2.55	40	550	3.1	430
Middle or 2d Voltage.	2.7	36.7	777		
Bottom or 3d Voltage	2.88	33.5	1150	3.57	900

This table shows that on the basis of useful life, for corresponding efficiencies, the GEM 100 watt lamp is a much better one than the 32 c-p. carbon. The higher first cost of the GEM, which is less than 20 per cent., is more than offset by the difference in life, as shown above. Every central station will find it desirable to adopt the 100 watt GEM in suitable voltage range in place of the 32 c-p. carbon, which should be abandoned. As the number of 32 c-p. lamps used is relatively small, the necessary number of 100 watt GEM lamps required to replace them can now be obtained.

An 80 watt GEM lamp giving 32 c-p. is supplied in the same size bulb as the regular 32 c-p. carbon for use where the larger bulb of the 100 watt GEM will not fit in shades or fixtures.

The Gem 50 Watt Lamp

The change to GEM from carbon lamps is not, however, confined to the high candle-power sizes. The 16 and 20 c-p. carbon must give way to the 50 watt GEM in the suitable voltage range, and this change has made a good start during the past two years. As the number of 16 and 20 c-p. lamps is very large, the change must needs be made gradually, to enable the manufacturer to transfer his production from the old to the new lamp. Making the change gradually seems to be desirable for the central station also, as it gives the company a chance to try out the lamps slowly and surely, and imposes what changes it brings in costs and power consumption in such a safely gradual way as to make them imperceptable in effect, if the increase in cost is not entirely nullified by the gains secured or induced.

The GEM 50 watt lamp, as is well known, is the same as the ordinary 16 c-p. lamp in bulb and general appearance, and, in fact, in all respects save filament. The filament is somewhat less affected by changes of voltage than the ordinary carbon filament, as it has the resistance characteristics of metal, thus giving an increase of resistance with increase of voltage, and a decrease of resistance with decrease of voltage—just the reverse of the ordinary carbon filament. The light given by this filament is of superior brilliancy and whiter color than that of the ordinary carbon lamp.

This lamp is therefore perfectly adapted to supplant the 16 c-p. carbon, as it will, in the corresponding efficiency, give equally satisfactory service and life performance. In adopting the GEM lamp care should be taken to select the lamp of suitable voltage range to give a life equal to that at present obtained from the carbon lamps.

As is well known, the GEM lamp is rated in total watts, and has a special form of label with three voltage markings known as first, second and third voltage. Stations at present using 3.5 watt per c-p. lamps therefore, will adopt the GEM 50 watt lamp at bottom voltage. Likewise stations using 3.1 watt per c-p. lamps will employ the GEM either at top or middle voltage. At middle voltage the lamp gives a longer life and lower renewal cost than the 3.1 watt per candle—16 c-p. lamp. The GEM lamp has the special advantage of enabling central stations, by employing the top voltage range, and without reducing their rates, to give their customers, for the same energy, twenty-five per cent. more light of greater brilliancy than that given by the carbon lamp at the bottom voltage.

Voltage Range	Watts per Candle	Hours Useful Life	Efficiency of Ordinary Carbon Lamp of Similar Life
1st or Top voltage...	2.55	525	3.1 w.p.c.—16 c-p.
2d Middle	2.7	730	3.3 —16 c-p.
3d. Bottom	2.88	1000	3.5 —16 c-p.

Companies heretofore using 3.5 watt per candle lamps can, without any change in rates, give their customers a reduction in bills of over 15 per cent. for the same illumination, and give an illumination of much greater brilliancy and attractive quality.

The only objection to the adoption of the GEM filament lamp is the increased cost, which is about 25 per cent. more than that of the carbon lamp. This slight increase in renewal cost can be and is being borne by many companies who are taking up this lamp, which they are furnishing to their customers on the same terms as carbon lamps. Where a company using 3.1 watt per candle lamps feels that it cannot stand any increase in renewal cost, they can, by adopting the GEM at middle voltage, offset the additional renewal cost and make a saving over the previous lamp renewal costs for carbon, besides giving customers 18 c-p. of light in place of 16 c-p.

Companies using the present 3.5 watt per candle lamps have a very low renewal cost, amounting to less than one-third of a cent per kw. hour, and could readily stand the slight increase over this low cost which the GEM lamp at bottom voltage, giving the same life, would entail. The many advantages enumerated above are worth far more than the addition to renewal cost involved in the adoption of these new lamps.

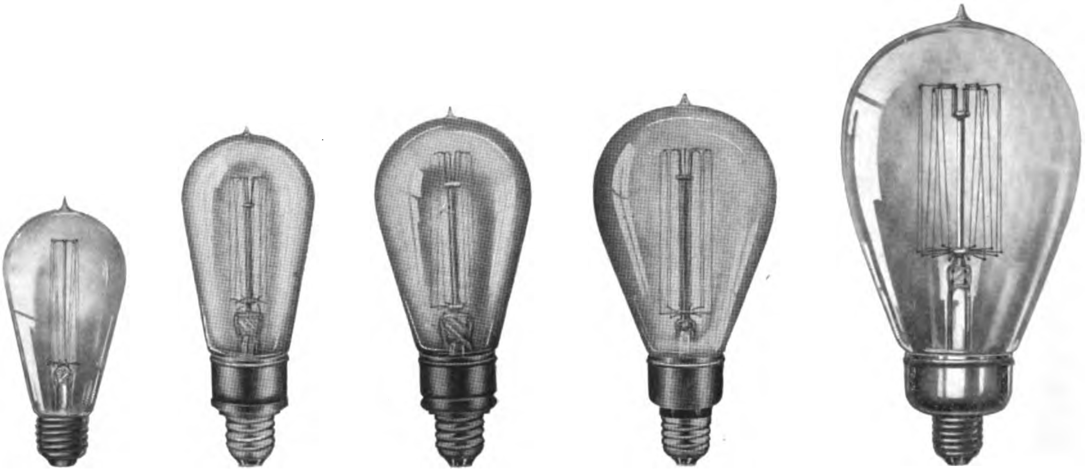
It is quite important that the GEM lamp be offered to customers on equal terms with the carbon lamp, as any excess charge will tend to materially retard its introduction. Experience has already shown this to be the case, and it is very desirable, therefore, that all companies arrange to offer this lamp on equal terms with present ones. The performance of the GEM 50 watt lamps, as demonstrated by actual tests upon a large number of lamps made during the past year, shows that the useful life will exceed that of the 16 c-p. carbon lamp, approximating an average of 525 hours useful life at an efficiency of 2.55 watts per candle. In individual performance the early GEM lamps had a slightly higher per cent. of early breakages than the carbon, but this was more than made up on the average performance. This percentage of early breakage has now been materially reduced, however, and it should be pointed out that the lamps should not be judged on the basis of individual life, but on the average performance.

The Tungsten Lamp

The filament of tungsten lamps is not a wire of metal like copper or iron wire. Tungsten it too brittle to be drawn, and although the metal has been known for considerably over a century, it is only in the past few years that it has been possible to build a wire of it, a feat which has given us the tungsten lamp.

In order to make a filament of tungsten, the fine particles of the metal powder (its general form) are made into a paste with some binding material and this paste squirted through a die, which die must be made from a diamond as the only material suitable. The filament so obtained is dried, the binding material removed by suitable processes, and the particles of tungsten welded together into a continuous wire.

Metallic conductivity is generally high, and to obtain the necessary resistance with tungsten for 100 to 125 volt lamps, long and very thin filaments are required. As such filaments are somewhat delicate and soften when burning, it is necessary to provide special means for their support. The General Electric Company support their filaments in their lamps with a special and clever form of anchor, which permits burning the lamps in any position, whereas most of the tungsten lamps can be burned only in a vertical pendant position.



General Electric Tungsten Lamps

Although the filament of the tungsten lamp is fragile, this difficulty can be and is being overcome by special methods of packing and greater care in handling the lamps. We have the evidence of the Welsbach mantle to prove that fragility is not a very serious difficulty. The early carbon filaments were as delicate and fragile as those of tungsten are now, and nobody would have then believed that a carbon filament would be made as durable as we know it to be to-day.

The General Electric Company in the past few months have shipped over 300,000 tungsten lamps to all parts of the country, with positive and direct information from most of the packages as to breakage. The results show an average not exceeding 1½ per cent. breakage, which result compares favorably with breakage on ordinary lamps.

A point of value occurs here. It is found that tungsten filaments while burning can not readily be broken; so if customers will keep lamps lighted while cleaning lamp, globe or fixture, the breakage will be minimized.

The positive temperature coefficient of tungsten (and tantalum) lamps causes them to suffer much smaller changes of candle-power and life for any change in voltage, than occur with the carbon filament lamp; all of which makes these new lamps better able to stand the fluctuations of service conditions than the old.

As is well known, the multiple tungsten lamps are now being made in this country in 25 watt, 40 watt, 60 watt, 100 watt, and 250 watt sizes, and to September 1, 1908, over 1,000,000 of such American made lamps have been made and sold. The available supply for the ensuing twelve months will be from 8,000,000 to 12,000,000 lamps. This will be enough to enable the central stations of the country to displace some gas arcs and take on additional business.

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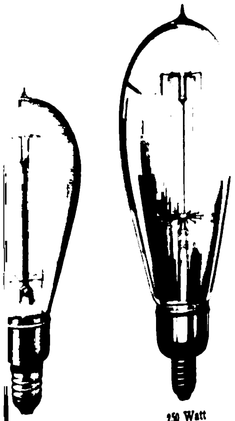

00 Watt

250 Watt

amps

positive temperature coefficient
en (and tantalum) lamps causes the
er much smaller changes of can-
and life for any change in voltage,
filament lamp

3	2.22	1.78	3.64	2.85	1.95	5.40	4.50	2.62	12.00	7.50	6.00
4	2.97	2.37	4.86	3.80	2.60	7.20	6.00	3.50	16.00	10.00	8.00
5	3.71	2.96	6.07	4.75	3.25	9.00	7.50	4.37	20.00	12 50	10.00
6	4.45	3.55	7.29	5.70	3.90	10.80	9.00	5.25	24.00	15.00	12.00
7	5.20	4.14	8.50	6.65	4.45	12.60	10.50	6.12	28.00	17.50	14.00
8	5.93	4.74	9.72	7.60	5.20	14.40	12.00	7.00	32.00	20.00	16.00
9	6.88	5.33	10.93	8.55	5.85	16.20	13.50	7.87	36.00	22.50	18.00
10	7.42	5.92	12.15	9.50	6.50	18.00	15.00	8.75	40.00	25.00	20.00
11	8.16	6.51	13.36	10.45	7.15	19.80	16.50	9.62	44.00	27.50	22.00
12	8.91	7.10	14.58	11.40	7.80	21.60	18.00	10.50	48.00	30.00	24.00

The accompanying table, Table III, gives some data on the various new lamps, including the tungsten, and will repay careful study

TABLE III

GENERAL DATA AND COSTS OF LAMPS AND SERVICE

	16 C.P. 50 W. Carbon	16 C.P. 56 W. Carbon	32 C.P. 100 W. Carbon	50 W. GEM (Top Voltage)	GEM (Bottom Voltage)	100 W. GEM (Top Voltage)	40 W. Tantalum	40 W. Tungsten	60 W. Tungsten	100 W. Tungsten
Total watts........	50	56	100	50	46	100	40	40	60	100
Hours life to 80% of c.p..........	500	1000	500	500	1000	500	800	800	800	800
Cost of lamp *.....	17c.	17c.	25.50c.	21.25c	21.25c.	29.75c.	38.25c.	84.15c.	$1.07	$1.34
Kw. hours during life.............	25	56	50	25	46	50	32	32	48	80
Cost of renewals per kw. hour.....	0.68c.	0.30c.	0.51c.	0.85c.	0.462c.	0.595c.	1.2c.	2.63c.	2.23c.	1.673c.
Cost per 100 hours of service for pr. at 10c. per kw. hour............	50c.	56c.	$1.00	50c.	46c.	$1.00	40c.	40c.	60c.	$1.00
Total cost of power and lamps per 100 hrs. service..	53.4c.	57.7c.	$1.00	54¼c.	48.3c.	$1.07	44.78c.	50.52c.	73.40c.	$1.167
Candle hours dur-										

The tungsten lamp is used to the best advantage with the bowl form of Holophane reflector, particularly with the frosted type which gives a very soft and agreeable lighting effect. From such a unit combination it is possible to obtain an illumination of four foot candles per watt per square foot upon a plane ten to twelve feet below the lamps, which result is four fold better than the average secured from ordinary lamps and shades.

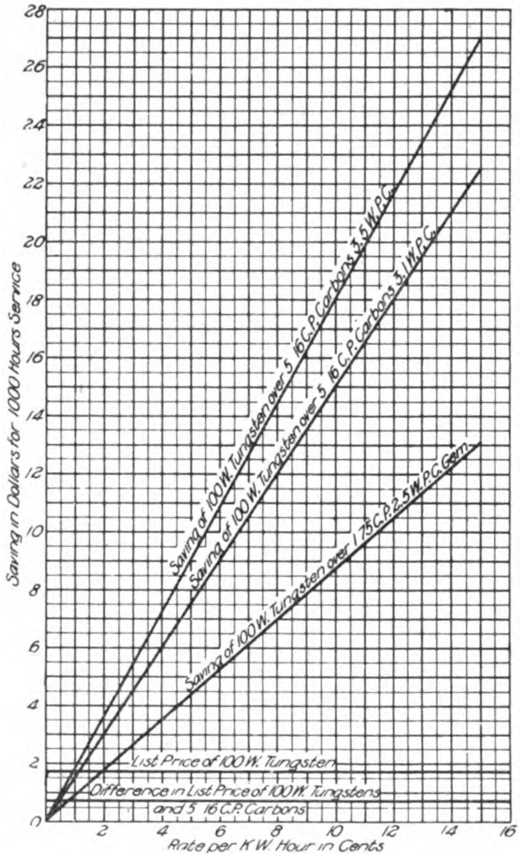

Fig. 1. Saving for Equal Illumination of 100-Watt Tungsten Over Other Lamps at Various Rates per Kilowatt Hour

It must be realized that the tungsten lamp in 40 watt and larger sizes is a radically new proposition in many respects. It is not a lamp to replace ordinary ones everywhere, as it has too large a candle-power and is too brilliant. It requires to be used in a somewhat more special way—above the line of vision, or in any event, suitably enclosed in frosted or opal globes, or shaded so as to avoid glare.

We have in the tungsten lamp a wholly new condition, as by reason of its very high efficiency, we are no longer required to depend upon the nearby illuminant, but can flood a room or shop with a daylight brilliancy, at reasonable costs, with lamps placed well above the view. Enclosed globes and spheres can now be economically illuminated to a full and satisfactory brilliancy. All previous limitations are removed, opening up a new era of daylight illumination.

We also have in the tungsten lamp a wonderfully attractive quality of light of the brilliant resplendency of sunlight, reproducing the daylight and bringing out every color in its true tone and shade.

Finally we have in the tungsten, a lamp that practically does not change in candle-power or brilliancy, giving a good long life of 800 hours or more, of (as far as the eye can tell) undimmed illumination.

The Central Station Policy

Improvements in lamps have heretofore indicated progress; the tungsten lamp means a revolution in the lighting industry. Its effect will be more far reaching than even that of the Welsbach mantle. Can there be any central station manager indifferent or antagonistic to the adoption of the tungsten lamp? If so, let him consider how he would like to be denied its use while a competing company employs it. What would have happened to gas lighting had there been no Welsbach light? It is not whether electric companies want the tungsten lamp, but rather what would become of them if they could not and did not get it. Many companies are too prone to consider only the possible effect on business in hand (generally under twenty-five per cent. of the entire lighting employed), and not look to the possibilities for new business to be reaped from the 75 per cent. or more lighting that is done by other illuminants.

Now the tungsten lamp can and should be employed primarily to secure new business. Let every central station take it and go after the people whom they have never been able to wean away from gas or oil, or who have gone back to gas or oil. Let your old customers know that you have the tungsten lamp and that they get them at a price, but *push* them with the unsecured ones and see the result. It is not necessary to do anything more than put the lamps in—they will talk for themselves far more eloquently than any one else can for them. You can count on holding the business; the lamps will never be ordered out.

Experience in electric lighting service has shown that it has been desirable policy for the central station to have as complete control and direction over the lamps used on their circuits as it is possible to obtain. This control has been given by the free renewal policy, which policy has quite generally prevailed with central station companies in this country. While the same principles, considered to be desirable with the carbon lamps, apply to the new lamps, the writer believes the relatively higher price of the latter makes it impossible to supply them on the free renewal basis, and it is necessary for central stations to make a charge to at least cover the additional cost of such lamps.

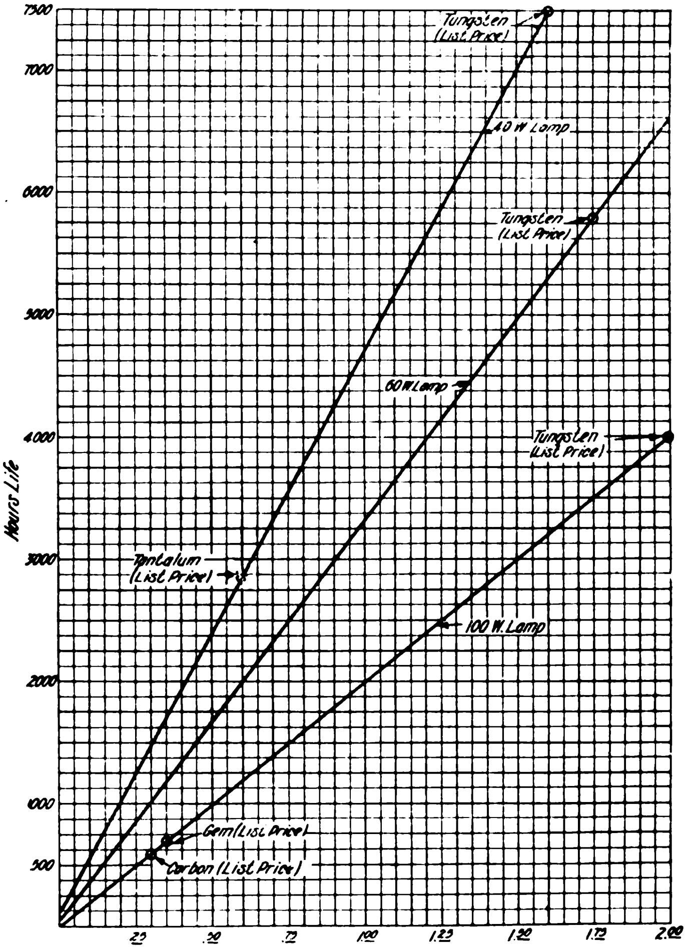

Fig. 2. Life Required for Various Lamps at Different Costs per Kw. Hour to Give 1/2 Cent per Kw. Hour Renewal Costs

Along this line of policy, therefore, it might be desirable to supply the original installation at full list price, and the renewals of the lamps at a lower figure than they could be purchased by the customer in the open market. The relative greater fragility of the tungsten lamps and the danger of breakage is deemed by some sufficient cause for charging the full list price for them; on the assumption that central stations must, for business policy reasons, guarantee every individual lamp's performance—something that the manufacturer cannot, of course, attempt to do.

Several companies have adopted the plan of furnishing the lamps without direct charge to the customer, by making a monthly maintenance charge per lamp therefor; after the plan that has been followed for years by gas companies with gas arcs, and also those with the glower lamps.

A fair monthly charge for the 100 watt tungsten lamp, on an average use of 2 to 4 hours per day, would be 25c. per lamp per month. In many cases it might be desirable to have the supply and maintenance of these lamps undertaken by a separate company, controlled by the lighting company; so that the collection of the charges for maintenance would not be involved with the central station company's account for current.

Table II shows the saving secured by tungsten lamps, and these values are diagrammed for the 100-watt tungsten in Fig. 1. The rates are shown at which one of these tungsten lamps will pay its full cost, or additional cost over equivalent lighting by carbon, in a given term of service—1000 hours. It will be noted that the 100 watt tungsten will pay its full cost in this time when the rate for current is one cent per kilowatt-hour, and its additional cost will be saved at any rate over ½ cent per kilowatt-hour. The corresponding values for the other lamps are also shown by the table, and it may be seen that the 40 watt lamp pays its full cost at any rate over 2½ cent per kilowatt-hour. For ordinary central station rates, and for equal illumination, these lamps will therefore justify and save their full cost several times over.

A word here as to the suggestion that the tungsten lamp be used at a lower efficiency, to secure a materially longer life and thereby permit reduced costs or free renewals thereon. The diagram (Fig. 2) shows the life necessary to secure a renewal cost of ½ cent per kilowatt-hour—which is about the average cost now obtained with the 3.1 watt per candle carbon lamps. It will be seen from this diagram that for the 100 watt tungsten, the necessary life to reduce the cost to that of the present carbon lamp is 3000 hours, and for the 40 watt lamp, 7500 hours. It should be needless to point out that such lives are wholly impracticable. With the ordinary use of lamps for two to three hours a day, 1000 hours life means a year's service, and this is about the limit of practical lamp life on which to consider renewal costs, etc.

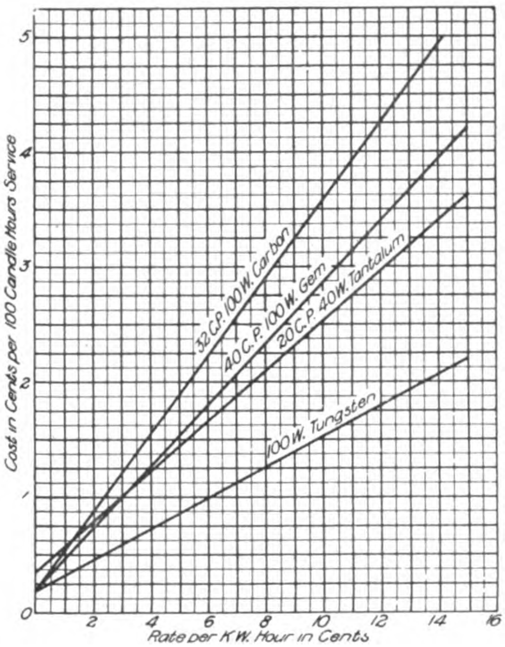

Fig. 3. Curve Showing Costs to Consumer of Approximately 100 Candle Hours of Light with Various Lamps Covering Cost of Power at Various Rates per Kw.-hr. and Cost of Lamp Renewals

Any longer life than a year introduces a continually increasing hazard of mechanical breakage from handling, cleaning, etc., under ordinary conditions of service. In any event, the special character of the tungsten lamp and its fragility render it easily possible for consumers, either maliciously or carelessly, to increase the breakage on the lamps to such an extent as to heavily increase the renewal cost to central stations attempting to supply such lamps on free renewal basis.

It would seem from these considerations that it is wholly impracticable to attempt free renewals through the plan of increasing the life.

The life of the tungsten lamp operated or handled with reasonable care is so good at regular rated efficiency of 1¼ watts per candle, that it is unnecessary to vary the rating thereon, as such variations tend to reduce the brilliancy and candle-power of the lamp and mar one of its chief advantages and attractions.

TABLE IV

COST PER CANDLE TO CONSUMER FOR VARIOUS LAMPS

Rates per Kw. Hr. in Cents	Total Cost of Lamps and Power per 100 Candle Power			
	33 C.P. 100 Watt Carbon	40 C.P. 100 Watt GEM	20 C.P. 40 Watt Tantalum	100 Watt Tungsten
1c.	.51	.43	.567	.416
2c.	.85	.70	.784	.552
3c.	1.19	.97	1.001	.688
4c.	1.53	1.24	1.218	.824
5c.	1.87	1.51	1.435	.96
6c.	2.21	1.78	1.652	1.096
7c.	2.55	2.05	1.869	1.232
8c.	2.89	2.32	2.086	1.368
9c.	3.23	2.59	2.303	1.504
10c.	3.57	2.86	2.520	1.64
11c.	3.91	3.13	2.731	1.77
12c.	4.25	3.40	2.954	1.91
13c.	4.59	3.67	3.171	2.05
14c.	4.93	3.94	3.388	2.18
15c.	5.27	4.21	3.605	2.36

In Table IV is shown the cost to a consumer of 100 candle hours of light at various rates per kilowatt hour, including cost of power and lamp renewals. The results of this table are diagrammed in Figure 3. This is an interesting diagram as showing rates at which various lamps qualify for giving the lowest lighting cost to consumers.

Figure 4 shows the hours life at which the tungsten lamps save their cost over carbon lamps at different rates per kilowatt-hour.

Tungsten Lamps for Street Lighting

The tungsten street series lamp is of equal, if not greater value than the tungsten multiple lamp in providing profitable business for central station companies. These lamps, as is well known, are listed in 32, 40, and 60 candle-power and ampere ranges from 3.5 amperes to 7.5 amperes at an efficiency of 1¼ watt per candle.

The accompanying diagram, Fig. 5, shows results of life and candle-power test on some tungsten series lamps, and it will be noted that the candle-power performance of practically 2000 hours is undiminished.

One of the eastern central station companies has obtained, in service test, a life of 1350 hours on these lamps. On the basis of 4000 hours' service per year this would only call for three renewals. A substantial saving per lamp can therefore be shown for the tungsten lamp over the carbon. A recent installation of these lamps at Adel, Iowa, has given the following comparison of saving to be secured.

This company installed an 8.6 kilowatt, 5.5 ampere constant current transformer complete with switchboard panel, a circuit of 82—40 c-p. tungsten lamps being supplied therefrom. These replace a lighting installation of 82—32 c-p. multiple carbon lamps. The saving in energy that this customer makes the first year will pay for the installation of the new apparatus and still show a net saving of over $115.00. The second year the saving will be over $413.00. This saving is obtained on the basis of 3 cents per kilowatt-hour and three renewals of lamps per year, as shown by the following statement:

COST OF NEW SYSTEM:	
8.8 kw. 5.5 amp. transformer and panel . . .	$298.00
246—40 c-p. 5.5 amp. tungsten lamps . . .	313.65
	$611.65
ANNUAL SAVING OVER OLD SYSTEM:	
In energy at 3 cents per kw	$556.50
Cost of 656—32 c-p. 3.5 watt per candle carbon lamps	170.56
	$727.06
Cost of new system .	611.65
Net saving	$115.41

The more interesting point is the comparison of street lighting costs of tungsten lamps in competition with gas. The 40 c-p. tungsten lamp, with its practically constantly maintained candle-power during life, will match the regular Welsbach street lamps, which, while it claims an initial candle-power of 60, declines so rapidly in candle-power that its average is no greater than the 40 c-p. tungsten lamp. The gas mantle using 3½ cubic feet of gas per hour will burn 14,000 feet during a year's service of 4000 hours, amounting to $14.00 at $1.00 per thousand, or $10.50 at 75 cents per thousand feet. Assuming the renewals of mantles in use, and the repair and attention to lamps as fixed to 3 cents per lamp per night (the figures used in recent Buffalo contract), the total cost

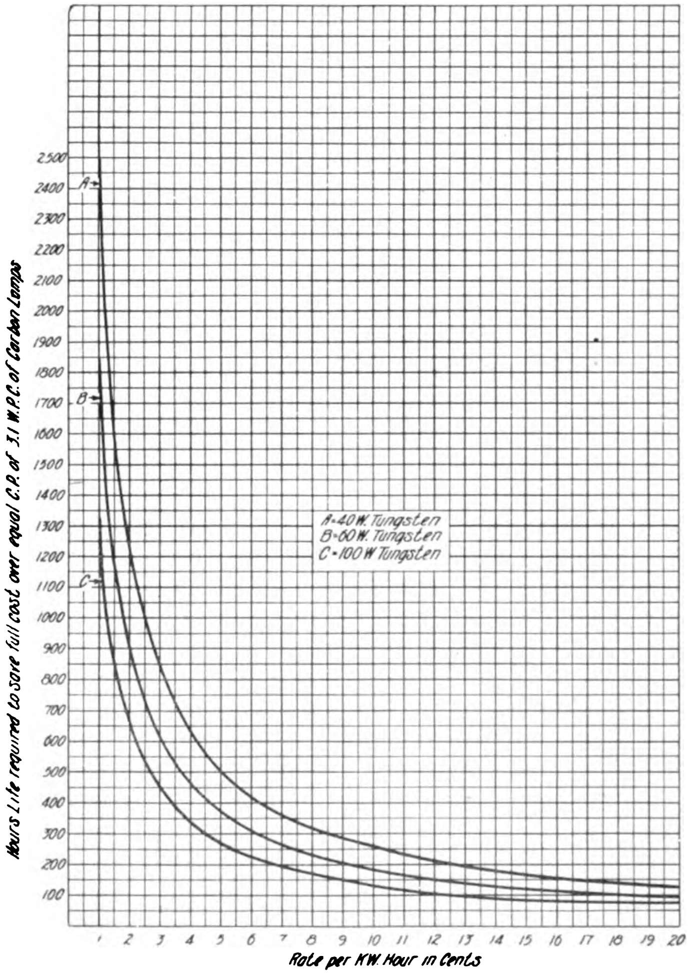

Fig. 4. Curves Showing Hours Life at which Tungsten 40, 60, and 100 Watt Lamps Save Their Cost over Equal Candle-Power of 3.1 W.P.C. Carbon Lamp at Any Rate per Kilowatt Hour

per lamp will be $24.95 with gas at $1.00 per thousand, or $21.45 with gas at 75 cents per thousand. Assuming four renewals per year as a conservative figure for the tungsten lamp, at a price of $1.27½ each to small users, we have about $5.00 for the lamp renewal cost for the tungsten. Deducting this from the renewal cost of the gas mantles of $10.50 leaves an excess of $5.50 for the gas mantles for the year. Adding this excess to the cost for gas at $1.00 per thousand ($14.00), we have a total of $19.50 per lamp as the figure to be paid for power.

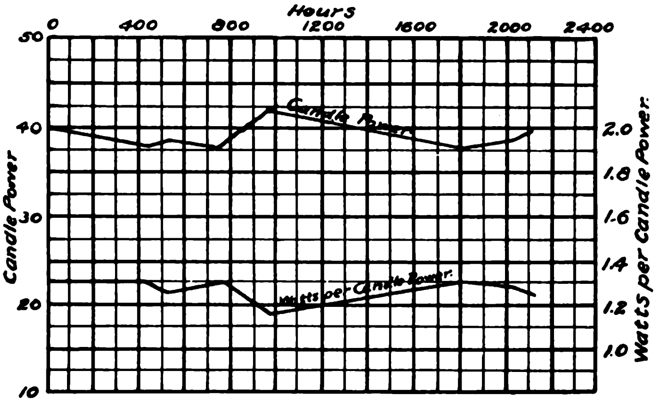

Fig. 5. Life and C.P. Curves Tungsten Street Series Lamps

The 40 c.p. tungsten lamp consumes 50 watts, or on the basis of 4000 hours' service, 200 kilowatt-hours; dividing $19.50 by 200 kilowatt-hours, we have a rate of nearly 10 cents per kilowatt hour which could be charged to meet the cost of gas. This rate, of course, is most remunerative for this class of service. Central stations could afford to make a materially lower rate than this and thus be able to effectually compete against Welsbach lamps for street lighting. In many cases incandescent lamps for street lighting possess many advantages, as the small units of light distributed at frequent intervals secure a uniformity of distribution that insures much better and more agreeable illumination than can be obtained with large units of light spaced at considerable distances apart.

The diagram, Fig. 6, shows the relative rates for tungsten and Welsbach gas lamps in street lighting service.

Although the mantle is rated at 60 c-p., tests recently made in three New England cities, on the gas mantle street lamp while operating under actual service conditions, show, as the following figures indicate, a wide variation in candle-power.

CITY	MAXIMUM C-P.	MINIMUM C-P.	AVERAGE C-P.
(1)	55.0	21.5	36.7
(2)	25.0	6.5	16.8
(3)	55.1	16.3	27.8

Hence, a 40 c-p. tungsten lamp, which maintains its candle-power practically constant throughout life, will give better average illumination than Welsbach lamps in any of the above cases.

Comparison of 40 c-p. tungsten series lamp with Welsbach mantle lamp:

Consumption per hour . .	3½ cu. ft.
Cost of gas at $1.00 per thousand for 4000 hours per year . .	$14.00
Renewals, repairs and labor at 3c. per night—per year (figures given in recent Buffalo, N. Y., contract)	10.95
Total cost per year Welsbach mantle	$24.95

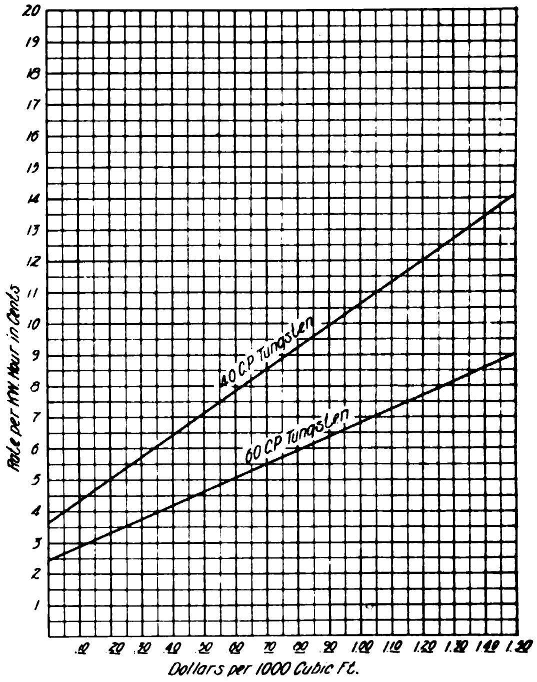

Fig. 6. Relative Rates for Current and Gas—Tungsten vs. Welsbach Street Lamps

series
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3.83

$21.12

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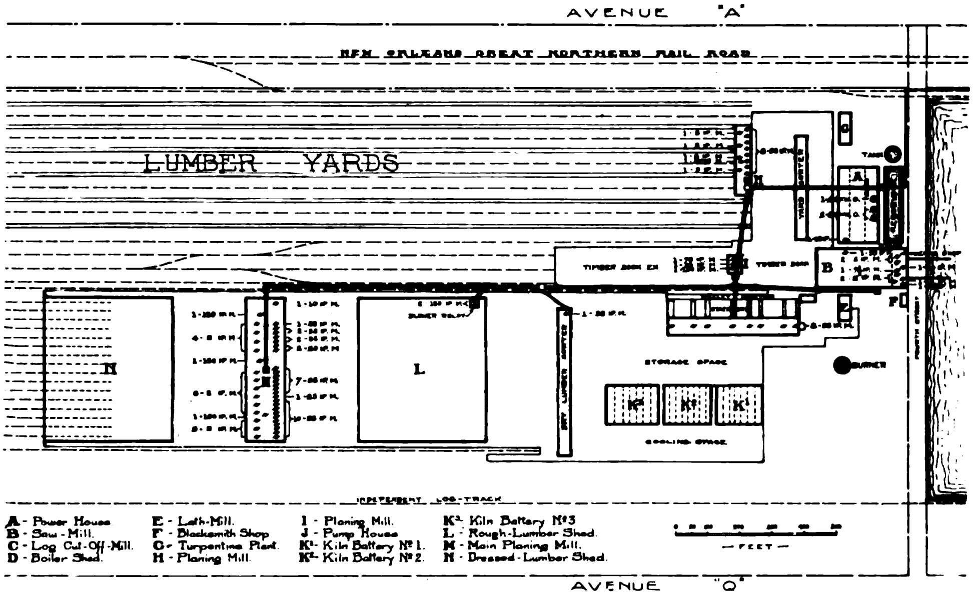
THE GREAT SOUTHERN LUMBER COMPANY.

The Largest Electrically Operated Lumber Manufacturing Plant in the World

By John Liston

The ideal attainment of modern production is a maximum output from a given investment in plant and machinery; and electric light and power, in so far as they contribute to this result, are being given an ever increasing degree of attention where woodworking machinery is used. Experience under the severest service conditions has proved that they possess advantages of efficiency and economy that meet most successfully the peculiar conditions of the lumber and woodworking industries.



Distribution of Electric Power—Great Southern Lumber Company, Bogalusa, La.

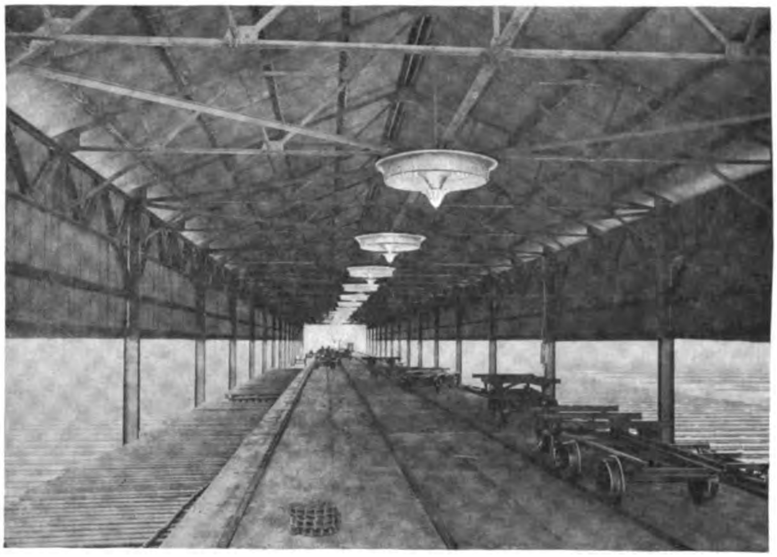
To the practical user of wood working machinery a brief description of the electrical equipment of the Great Southern Lumber Company's plant at Bogalusa, La., will present graphically the inherent advantages of electric light and power. This is at present the largest electrically operated lumber manufacturing plant in the world, and has an annual production of 175,000,000 feet of lumber. There are eighty-one General Electric motors in use in the various buildings, ranging in capacity from 5 h.p. to 150 h.p., with a total capacity of 2767 h.p.

The conditions at Bogalusa are typical of those usually met in lumber handling. The buildings are not compactly grouped but are arranged for attaining a maximum production, and much of the machinery is of necessity located at a distance from the main saw mill. Under the old conditions of purely mechanical transmission of power this would have involved an almost prohibitive transmission loss, or the expensive alternative of installing a number of separate steam power plants, with their attendant heavy charges for maintenance and operation; but with electric power the energy developed is readily distributed with a practically negligible loss. At the Bogalusa plant all the machinery with the exception of the tree mill, which has a separate power plant, is operated from one generating room.

By centralizing the generation of power the cost of attendance has been reduced to a minimum, while the ease with which the electric current can be transmitted and controlled renders the problem of providing for possible additions to the present equipment relatively simple.

In addition to supplying power for all machinery, the plant is electrically lighted throughout, and current is also provided for lighting the streets and houses of the mill town.

The power house provides both alternating and direct current service and is equipped as follows:



Shed Used for the Grading of Kiln Dried Lumber. Lighted by General Electric Enclosed Arc Lamps Fitted with Light Balancing Ceiling Diffusers

Power House Equipment

Two 500 kw. three-phase 2300 volt 100 r.p.m. revolving field General Electric generators, direct connected to Corliss engines.

One 200 kw. three-phase 2300 volt 100 r.p.m. revolving field General Electric generator, direct connected to Corliss engine.

Two 30 kw. 125 volt engine type exciters.

Two 50 kw. 250 volt motor-generator sets for supplying current to the direct current motors in the machine shop.

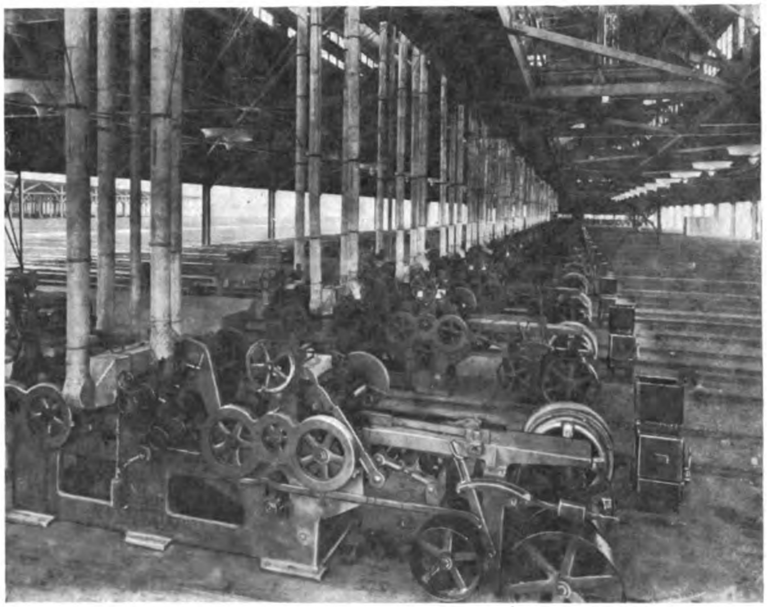
Complete switchboard consists of:

Three generator panels.
Two exciter panels.
Twelve feeder panels.
Two motor-generator panels.
Two luminous arc lighting panels.
Two series A.C. lighting panels.

Two 50-light constant current transformers and mercury arc rectifiers for supplying current to the luminous arc system installed on the towers in the mill yard.

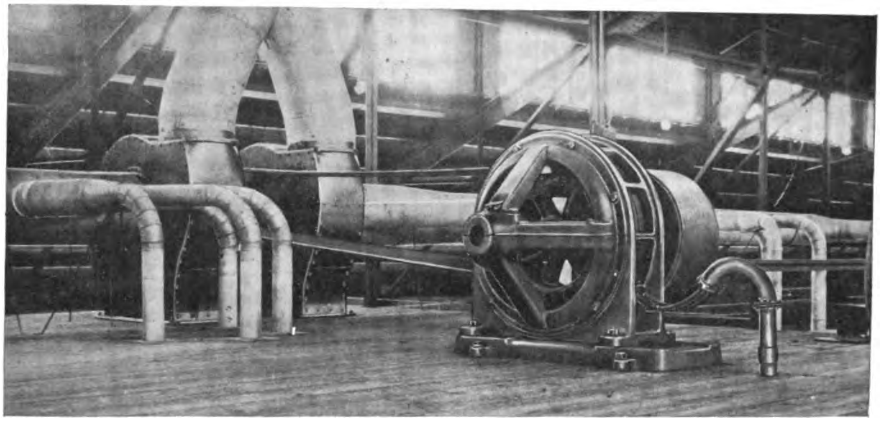
Three 25-light constant current transformers for supplying alternating current to arc lights in the streets of the mill town.

The current is generated and transmitted at 2300 volts A.C., the pressure being reduced by means of transformers to 440 volts, for which voltage the A.C. motors are designed. A few D.C. variable speed motors are used in the machine shop, and these are supplied by means of a motor-generator set. The type of A.C. motor used is the well-



Interior of Planing Mill Showing a Bank of Berlin Matching Machines, each Driven Independently by a General Electric Form K Induction Motor

known General Electric Form K induction motor, which is simple and strong in construction and capable of maintaining high efficiency over a wide load range. It requires practically no attention while running, and is able to carry large overloads for considerable periods without serious over-heating. In addition to this, it is quick and certain in starting under load, and the starting apparatus is extremely simple. These characteristics insure continued operation under the severest service conditions that are met in woodworking plants. and formed the principal reason for the adoption of the K motor for constant speed work throughout the Bogalusa plant.



Two 70 in. Sturtevant Blowers, Driven by a 150 h.p. General Electric Form K Induction Motor, Belt Connected

The equipment includes both individual and group systems of motor drive, the majority of the machines being operated by individual motors, either direct-connected or belted to the machine shaft. The filing room machinery is operated by motor driven shafting. The motors are equipped with compact starting devices and protected by fuses, so that each machine or each shaft-driven group is a plant in itself and practically independent of the other machines. In case of a single machine breaking down, or being stopped for repairs or adjustment, the advantages of this arrangement are obvious.

In a woodworking plant the question of fire risk is of vital importance, and in the Bogalusa equipment the fuses are inclosed and arranged to protect both the motor and cable from internal injury. The cables themselves are encased in iron conduits, and since the induction motor is without a commutator, sparking is avoided and the danger of fire from the electrical equipment is practically eliminated.

A reference to the accompanying illustrations of the Bogalusa plant will show how the use of motor drive has obviated the use of overhead shafting and belts, and thereby greatly simplified the problem of interior lighting. The following list of motor driven machines demonstrates the flexibility of the system employed.

Motor-driven Machines

Machinery	MOTORS			
	No.	H.P.	R.P.M.	*Drive
Planing Mill No. 1				
13—16" No. 238 trim saws	13	5	1200	D
17—No. 94 planers and matchers	17	35	900	D
2—No. 266 3-saw gang edgers	2	35	900	B
1—64" No. 285 band rip saw	1	55	514	D
1—44" No. 283 band rip saw	1	25	600	D
1—44" No. 281 band rip saw	1	25	600	D
2—15" inside molders	2	20	....	D
1—30" No. 177 double surfacer	1	35	900	D
3—Double 70" Sturtevant blowers	3	150	600	B
All machinery in the filing room	1	10	1200	B
Planing Mill No. 2				
8—No. 94 planers and matchers	8	35	900	D
1—44" No. 281 band rip saw	1	25	600	D
4—16" No. 238 trim saws	4	5	1200	D
1—Double 70" Sturtevant blower	1	150	600	D
Planing Mill on Timber Dock				
1—30"x20" No. 1 timber sizer	1	85	900	D
1—No. 94 planer and matcher	1	35	900	D
1—Double Sturtevant blower	1	150	600	D

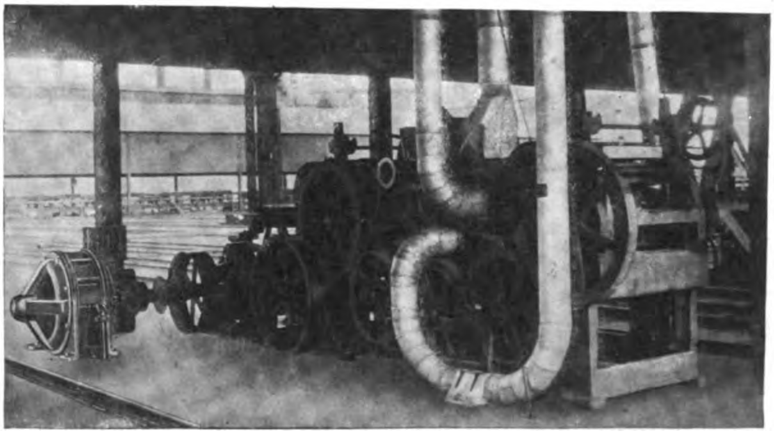
Dry Lumber Sorter				
Dry lumber sorter	1	35	900	B
Lumber Stackers				
8—Lumber stackers	8	25	600	B
Fuel Conveyors				
2—Fuel conveyors	2	35	900	B
Centrifugal Pumps				
2—14" Centrifugal pumps for pumping on to log ponds	2	85	720	D
Relay Blower Station				
1 Double 70" Sturtevant blower	1	150	600	B
† Machine Shop				
1—Upright drill	1	2		
1—Bolt cutter	1	2		
1—Planer	1	7½		
2—Pipe machines	2	2		
1—Shaper	1	3½		
1—Radial drill	1	5		
1—Machine lathe	1	3½		

* Drive D Direct Coupled
B Belted
† D.C. Variable speed motors.

sufficient to carry away dust and fine shavings, but also knots and large chips.

In designing the Bogalusa plant, the problem of efficient interior lighting was carefully considered, with the result that a General Electric enclosed arc lamp, using a light balancing selective ceiling diffuser, was finally adopted. This combination practically eliminates shadows and insures an even distribution of light over all parts of the area illuminated by each lamp, thus enabling the operators to run the machinery at night under approximately daylight conditions. All necessary auxiliary lighting is provided for by means of incandescent lamps. A reference to the accompanying illustrations will show how thoroughly the matter of providing adequate light has been carried out.

For illuminating the mill yards, eight steel towers have been erected, and on these seventy General Electric luminous arc lamps have been installed. This method insures well distributed light over large areas and avoids any possibility of the wires interfering with the handling of lumber in the yards. The steel towers are supplemented by 16 poles provided with one arc lamp each. The substantial construction of the luminous arc lamp and the long life per trim obtained, together with the intense illumination provided, enables outdoor night work to be carried on with practically no diminution of productive efficiency. In addition to the a
lights in the lumber plant proper, ei
three A.C. arc lamps are provided for



Berlin No. 94, 9 in. by 6 in. and 15 in. by 6 in. Planer and Matcher, Driven by a 35 h.p. General Electric Form K Induction Motor

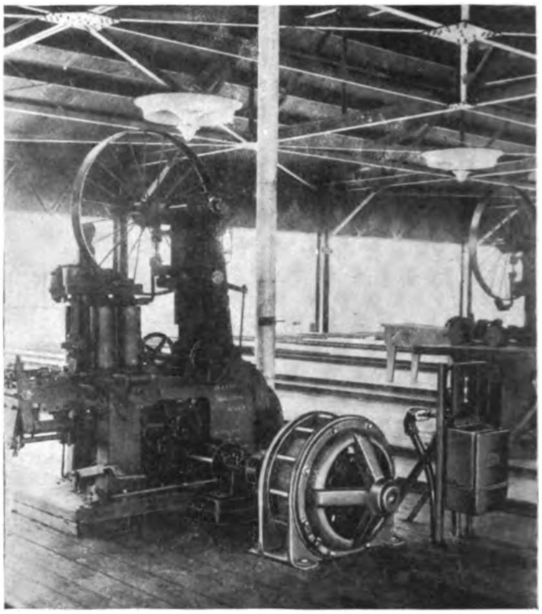
In order to obtain the best working conditions for the men and eliminate the dust nuisance which is so commonly met with in saw mill work, an elaborate exhaust piping system has been installed. It is served by seven motor-driven double blowers distributed through the mills, and about 8 oz. constant pressure is maintained. This is not only the streets of the mill town. The distribution of the lighting system is as follows:

Lighting Distribution

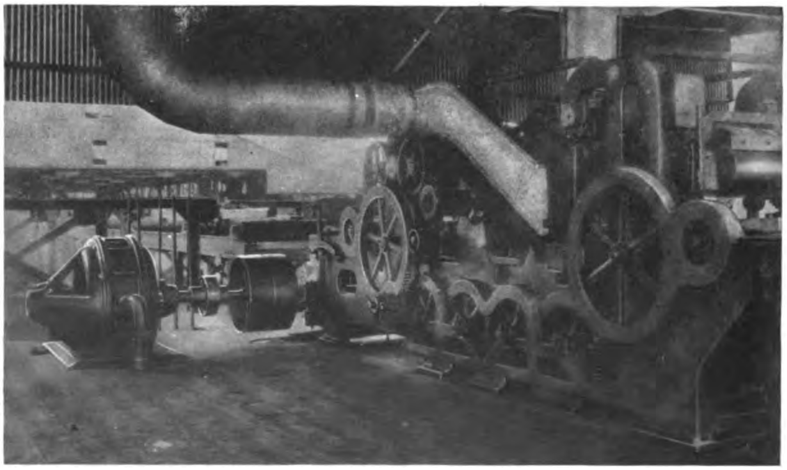
Location	Incandescent Lamps	Arc Lamps
Saw mill	247	57
Yard sorter	..	10
Dry lumber sorter	20	16
Planing mill No. 1.	20	32
Power house	103	10
Timber docks	150	..
Planing mill No. 3	..	8
Sizer shed	..	3
Dry kilns	50	..
Rough dry shed	432	..
Shingle and lathe mill	26	7
Lumber stackers	40	8
Mill supply room	60	..
Mill yard	..	86
Mill town	..	83
Total	1148	320

A comparison of the conditions at the Bogalusa plant with those found in wood-working plants using mechanical drive will show that the selection of electric light and power has increased the factor of safety to a marked degree, both as regards machinery and operatives, at the same time resulting in a practical elimination of the fire hazard, especially from open flames and hot boxes. The absence of overhead shafting and belting permits the proper distribution of light and air, and also renders it possible to so locate the machinery as to obtain an ideal sequence of operations. This avoids re-handling of work, with its attendant expense, damage and congestion. It is also possible to operate any individual machine overtime or at unusual hours without putting the whole equipment of the plant in operation.

The floor space required for a given amount of product has been reduced to a minimum, and the illustrations show the conditions of cleanliness and safety which characterize this particular plant. In short, the entire installation is one that exemplifies the efficiency and economy obtained by the use of electric light and power in modern lumber manufacturing.



Berlin No. 283, 44 in. Band Re-saw Operated by Direct Connected, 25 h.p., General Electric Form K Induction Motor



Berlin No. 1, 30 in. by 20 in. Timber Sizer, Driven by an 85 h.p. General Electric Form K Induction Motor

THE ENERGY OF STEAM

PART I

BY J. W. KIRKLAND

These rather elementary facts as to steam and the phenomena accompanying its expansion have been prepared with the idea that they will assist in pointing the way to correct thinking on the part of those who, not being specialists, are sometimes called upon to consider problems relating to engines, turbines, boilers and condensers. The principles involved are not difficult to grasp provided that one begins with correct fundamental conceptions. Incomplete or wrong ideas sometimes lead to such fallacies as that condensers are less effective at great altitudes than at sea level, or that the principal reason for increased economy obtained by working an engine down to vacuum is due to the elimination of the back pressure on the piston on its return stroke.

Steam and Heat

In dealing with steam we have to consider it as a vehicle of heat, and that it is its heat contents which is transformed into work. Steam is an elastic gas, and like all other gases is capable of doing work by expansion, during which its temperature and pressure decrease and its contained heat is diminished by an amount equivalent to the work done. Heat can only be transformed or transferred with a fall of temperature, and the amount of work obtainable from any working fluid is some function of the difference of temperature existing at the beginning and end of the expansion. The greater this difference, the greater is the available energy, and, furthermore, the greater is the efficiency attained. For example, if one pound of steam at a pressure of 150 lbs., corresponding to a temperature of 366° F., be allowed to expand to atmospheric pressure and a temperature of 212° F., the theoretical energy available will be about 135,000 ft. lbs., while if expanded to one pound, which corresponds to 102° F., the energy will be 250,000 ft. lbs.

A law of the perfect heat engine is that its efficiency is expressed by the range of the absolute temperature through which it works, divided by the absolute initial temperature, the absolute zero of temperature being calculated to be $-460°$ F. An analogy which throws light on this law is that of a lake of water on a mountain. The mass of water in the lake may be considered as analogous to the heat contents of a quantity of steam, the height of the lake as initial steam temperature, and sea level as absolute zero. Evidently, if a water wheel is installed at sea level so as to use *all* of the head, the power and the efficiency are both maximum; while if the water wheel is installed at a higher level, the power is decreased and the efficiency is less, because of the energy left in the water as it finds its way downward from the water wheel, the discharged water being analogous to the heat discarded in exhaust steam from an engine. The efficiency may therefore be expressed as the ratio of the head used to the total elevation of the lake. The efficiency so expressed, which we might call the efficiency of location, must not be confused with the efficiency of transformation of one form of energy to another. In either a water wheel or a heat engine, the efficiency of transformation depends upon the perfection of design and construction. The efficiency of location in the case of a water power plant is usually far from 100 per cent., because it is not practical to build pipe lines, from lakes situated on mountains, all the way down to the sea. Also, in a heat engine the efficiency (called in this case the thermo dynamic efficiency) is always far from perfect, because we cannot discharge the heat at absolute zero temperature, but must do so at a temperature slightly higher than that at which we live. We are limited in practice to a discharge temperature of at least 70° F., or 530° F. above absolute zero—the "sea level" of heat. Expressing this condition numerically, and assuming that we have steam at 366° F. (corresponding to 165 lbs. absolute, or 150 lbs. gauge pressure), and that we discharge it at 212° F. (atmospheric pressure), the theoretical thermodynamic efficiency is seen to be

$$\frac{(366+460)-(212+460)}{366+460}=18.6 \text{ per cent.}$$

Supposing now, that instead of discharging the exhaust steam at atmospheric temperature, we condense it and work it down to 1 lb. pressure above a perfect vacuum, at which pressure its temperature is 102°. The fraction expressing the efficiency then becomes:

$$\frac{366-102}{826}=32 \text{ per cent.}$$

The improvement in economy by condensing is seen to be caused by increasing the temperature and pressure range through which the steam is worked.

It must not be inferred that the figures arrived at by these theoretical calculations do more than point out a principle. In practice the improvement in efficiency due to vacuum, especially in steam engines, though to a much less extent in steam turbines, falls far below the theoretical maximum.*

Since steam is to be considered with relation to heat, it is important to consider its heat contents under various conditions. We do not know the total amount of heat carried by steam or by any other substance. We *do* know, however, with great accuracy, the amount of heat, *over and above that contained in water at its freezing point*, which is contained in water or steam, or in a mixture of the two, at all practical temperatures and pressures. This knowledge is, fortunately, sufficient for all useful purposes. We also know accurately the pressures and volumes corresponding to various temperatures. These physical properties are published in steam tables, such as that of Cecil H. Peabody.

These tables relate to saturated steam. As applied to steam, the term "saturated" relates to saturation with heat. It conveys the idea that the steam contains all of the heat that corresponds to its pressure and temperature and no more. If, from a quantity of saturated steam, heat be abstracted (as by radiation, or in the process of doing work), a part of the steam must condense, and a steam and water mixture must remain. If, on the other hand, heat be added to a quantity of saturated steam, the latter will become superheated. Superheated steam means steam of higher temperature than that corresponding to its pressure; and if any water be introduced into such steam, it will be evaporated until (if there be enough water) the temperature of the steam will fall to that of the saturated state. All substances which are normally in a gaseous state under the conditions in which we live, may be considered to be superheated vapors; and likewise, superheated steam may be considered much as an ordinary gas.

From the definition of saturated steam, it is readily seen that such steam exists normally in contact with water, and that superheated steam *cannot* be in contact with water. Steam in contact with water is thus always in a saturated condition and has the temperature corresponding to its pressure; it also weighs a certain definite amount per unit of volume for each pressure and temperature. Saturated steam may be either dry or wet. Steam is referred to as "dry" when it contains no particle of water, yet is not superheated.

It is useful, before considering what happens to steam when doing work and giving up heat, to trace the changes it undergoes while being heated. Consider a pound of water at the temperature of freezing (32° F.), but *not* frozen. As heat is supplied to the water, its temperature rises almost uniformly to the point where the water begins to boil; as still more heat is supplied the water boils away, remaining at the same temperature (if at the same pressure) until it is completely evaporated. As still more heat is applied to the steam it is superheated (provided it is contained in a closed vessel), and its temperature rises above that of the boiling point.

The rise of temperature for each heat unit supplied to a given body of matter depends upon the specific heat of the substance of which the body is composed. A heat unit in our ordinary notation is that quantity of heat which will raise the temperature of one pound of water one degree Fahrenheit. It is termed a British Thermal Unit, and is written B.t.u.

It follows from the definition of a heat unit that the specific heat of water is 1; that is, the temperature of one pound of water rises one degree with the addition of one heat unit. This is substantially correct for all ordinary temperatures. The specific heat of steam, however, is quite different from that of water, and is 0.48 for saturated steam at constant pressure varying from that value upwards for the superheated conditions.

Fig. 1 is drawn with abscissæ proportional to added heat units, and ordinates proportional to temperatures (Fahrenheit). The line o–a is at an angle of 45 degrees, since the specific heat is unity, and since a division of one scale represents one degree; and of the other, one heat unit. The line a–b represents by its length the latent heat of steam at 212° F. and 14.7 lbs. absolute pressure. It is that part of the total heat of steam which represents the work of transforming one pound of water into steam; the "total heat" meaning all heat added to the water in raising it from a temperature of 32°. It is seen that the total heat of steam at 212° is about 1147 B.t.u., of which 180 B.t.u. have gone towards heating the liquid, and 967 B.t.u. represent latent heat. The part of the total heat which is shown by a change of temperature is referred to as *sensible* heat. Considering the latent heat, it is clear that this must be spent in producing two quite distinct phenomena. First, it is expended internally in overcoming the mutual attraction of the molecules of water—spreading them apart to the attenuated condition of a gas; second, in making room against surrounding pressure for the increased volume occupied by a quantity of steam as compared with an equivalent quantity of water. This latter is called "heat equivalent of external work," and is very easily calculated when we know the volumes occupied by a pound of steam and a pound of water at a given temperature.

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*Footnote: This relation of efficiency to temperature range applies only to an elementary, or so-called perfect engine working with a perfect gas. It is only approximately true for steam in a saturated state.

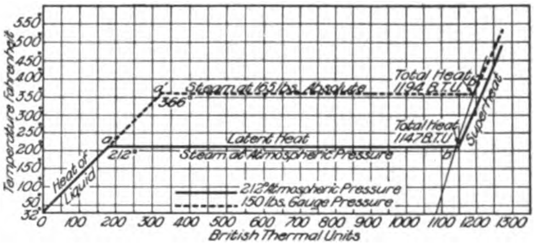


Fig. 1

Now let us assume that the water is heated in a boiler under 150 lb. above atmospheric pressure, or say 165 lb. above perfect vacuum. The dotted line in Fig. 1 shows the temperature and corresponding heat. The temperature of saturated steam at this pressure is 365.9° F., and its volume per pound is 2.751 cu. ft. The total heat is given by the steam table as 1193.6 B.t.u., and of this 855.6 B.t.u. is the latent heat and 338 B.t.u. the heat of the liquid. The latent heat at this pressure is seen to be less than that at atmospheric pressure. This points out the fact that while, of course, the total heat of steam is greater the higher the temperature, it requires less heat actually to cause ebullition at high than at low temperatures and pressures.

It will be noted that the total heat of one pound of saturated steam at 165 lbs. pressure is only 47 B.t.u. (about 4 per cent.) greater than that of one pound of saturated steam at 14.7 lbs. If only this difference in heat contents were available in work from steam expanding between these limits, the available energy would be only $47 \times 778 = 36{,}500$ ft. lbs. (778 ft. lb. = 1 B.t.u.) But as a matter of fact, we know that the available energy between these pressures is about 130,000 ft. lb., or almost four times as much. Whence comes this apparent excess? It is due to the partial condensation of steam into water while expanding and doing work, and the liberation of the latent heat of the portion so condensed. In other words, the heat discharged will not be that of one pound of saturated steam at the lower pressure, but that of the mixture of steam and water resulting from the expansion. This moisture, in the case cited, will amount to about 13 per cent. of the weight of the steam, or 0.13 lb. Eighty-seven per cent. by weight of the exhaust will be saturated steam at 14.7 lbs. and 212° F.; so we may write the heat contents of the exhaust as follows:

Steam	0.87×1147	$= 998$ B.t.u.
Moisture	$0.13 \times (212 - 32)$	$= 23.4$ B.t.u.
		1021.4 B.t.u.

The heat which has been transformed into work under the assumed condition of perfect expansion is, therefore, $1193.6 - 1021.4 = 172.2$ B.t.u. = (approximately) 130,000 ft.lbs. Suppose that we work the steam down to 1 lb. absolute pressure. The difference between the total heat of steam at 165 lb. and 1 lb. is found by the steam table to be 80.5 B.t.u., or 62,600 ft. lb. In this case the available energy is really 250,000 ft. lb., or 322 B.t.u. Since the total heat of one pound of saturated steam at one pound pressure is 1113.1, and the temperature corresponding to that pressure of steam is 102° F, by representing the fraction of the original steam remaining by X, we may write: Available energy in B.t.u. $= 322 = 1193.6$ (the total heat of steam at 165 lbs.) $- [1113.1X + (1 - X)(102 - 32)]$ (the heat exhausted).

Solving, X = steam exhausted = 0.77 lb.
$(1 - X)$ = water " = .23 lb.

So, knowing the percentage of moisture resulting from expansion under theoretical conditions, we may calculate the available energy; or, on the other hand, knowing the available energy, we can calculate the moisture which must have been produced. Calculation to determine both available energy and moisture, from fundamental consideration, are somewhat complicated and would be out of place in this article.

If expansion be conceived to be complete to absolute zero of pressure and temperature, the volume becomes infinite, the weight of the vapor occupying this volume zero, and the moisture produced equal in weight to that of the original quantity of steam. This is the condition for 100 per cent. thermodynamic efficiency. Efficiency of transformation is the ratio of the useful work done by a prime mover to the available energy existing in the working fluid between the limits of initial and discharge pressures. For instance an engine, fitted with a condenser producing a vacuum of one pound pressure, and requiring 20 lb. of steam at 165 lb. pressure to produce one kilowatt hour, receives in an hour steam having $20 \times 250{,}000 = 5{,}000{,}000$ ft. lb. of available energy. One kilowatt hour is equivalent to 2,650,000 ft. lb., so the efficiency of transformation in this case is $\frac{2{,}650{,}000}{5{,}000{,}000} = 53$ per cent.

Earlier in this article the thermodynamic efficiency for these conditions was determined to be approximately 31.3 per cent., so the total efficiency of the engine with respect to the heat supplied to it is equal to $0.53 \times 0.313 = 16.5$ per cent. If the efficiency of combustion of the boiler be taken to be 70 per cent. the total efficiency is reduced to 11.5 per cent. Consequently a pound of coal which contains say 14,000 B.t.u., would deliver 1610 B.t.u., or 1,250,000 ft. lb. in useful work. Evidently slightly more than 2 lb. of such coal would be required per kilowatt hour under the conditions assumed.

It is seen from the foregoing that by far the greater part of the total heat of steam is its latent heat, and that when steam is used in an engine or turbine, most of the heat which is realized as work comes from the latent heat liberated by the partial condensation of the steam. The amount of moisture in the exhaust of an engine or turbine (less that caused by radiation of heat from cylinders, casings, etc.) is, in a way, a measure of the efficiency secured in working the steam; for such water will have given up its latent heat as work, while all steam exhausted contains latent heat which is wasted as far as work is concerned.

A part of the latent heat of exhaust steam is recoverable, with good efficiency, for useful purposes in certain cases, as for instance, for heating feed water. In the case of a non-condensing engine, every pound of exhausted steam is capable of raising the temperature of seven or eight pounds of feed water from 70° to 200°, and the difference in fuel efficiency, as between boiler feed water at these two temperatures, is about 10 per cent. In the case of a condensing engine or turbine, if exhaust steam is not otherwise available, it is evidently desirable to take sufficient steam from the receiver, or a convenient stage of the turbine, to heat boiler feed water, since practically all of the heat of the steam so taken will be used with almost 100 per cent. efficiency; whereas, if worked down to the condenser temperature, only a small fraction of its heat, at best, can be converted into work. It follows, that in a condensing steam plant, auxiliaries such as pumps and exciters can often best be driven by non-condensing engines of which the exhaust steam is used for heating feed water.

Reference has been made to superheated steam; that is, steam heated to a temperature higher than that corresponding to its pressure. Such steam is like any other gas which requires normally to be compressed and cooled in order to become liquid. When a superheated vapor expands, it falls in temperature and liberates heat which is available for transformation into work. The amount of heat liberated depends upon the specific heat of the gas, that is, the amount of heat required to raise the temperature of one pound of the gas one degree. Reference to Fig. 1 will show that the amount of heat necessary to produce any temperature of superheat is small compared to the latent heat of the steam at that temperature. We see the result of this fact in the construction of boilers with superheating tubes. Although these may add as many degrees of temperature to the steam as are added to the feed water by the main tubes of the boiler, they need impart so comparatively little heat that a few of them, far removed from the fire, are sufficient.

Steam engines or turbines may work with steam which is superheated at the throttle valve, but with any practical degree of superheat the steam falls very quickly to the temperature of saturation corresponding to its pressure, and the exhaust from a cylinder or from a turbine is practically always a mixture of steam and water, no matter how high the initial superheat.

Expansion of Steam

When steam expands by virtue of its heat energy, that is, without gain of heat from other bodies, its pressure and temperature decrease, and its volume increases according to natural laws, the mathematical expressions of which involve data secured by experiment. In expanding, the steam is, as has been stated, subject to partial condensation. Such expansion, described in text books as "expansion without gain or loss of heat," is termed *adiabatic*.

It is sufficient for the purpose of this article to say that the relation of volume to pressure in adiabatic expansion is represented by the equation $pv^k =$ a constant. The exponent k is a constant for saturated initial condition and equals 1.135.

Fig. 2 is a curve of the relation of pressure to volume, according to this formula, for an initial pressure of 165 lbs. We might trace with the same co-ordinates a curve showing the relation of pressure to volume with constant temperature, or an *isothermal* curve. Such a curve would be only of speculative interest, as it would represent a condition in which the steam in expanding loses no heat and does no work; the work represented by the increased volume necessarily being represented by heat given to the steam from an outside source. Such a theoretical conception of expansion is expressed by $pv =$ a constant.

A curve showing the volumes corresponding to various pressures of *saturated* steam is also traced on Fig. 2. This curve is not derived from a formula but is taken from the steam table. For any given pressure, the difference of volume between the adiabatic curve and that of saturation represents the amount of condensation which has occurred due to expansion.

For any pressure existing during expansion, the temperature of the resulting mixture of steam and water is that of saturated steam at that pressure.

In practice the form of a steam expansion curve differs from the adiabatic to a greater or less extent. It is affected by losses of heat from radiation, and consequent condensation; by leakage of steam into and out of the vessel in which the steam expands; and, for instance, in an engine cylinder, by initial condensation due to walls colder than the incoming steam, and later, re-evaporation due to walls warmer than the expanded steam toward the end of a stroke.

Since change of volume times pressure represents work, an adiabatic curve shows graphically the theoretical energy of expanding steam. For instance, the area enclosed between the points a b c d a in Fig. 2 represents the maximum work of which a pound of steam is capable while expanding from 165 lbs. to 20 lbs. The rectangle a e c d represents the "heat equivalent of external work," to which reference has been made in a preceding paragraph. It is the work done against a pressure of 165 lb. per sq. in. (= 23760 lb. per sq. ft.) by a pound of water under the influence of heat, in increasing its volume from 0.016 cu. ft. to 2.751 cu. ft. (the volume of a pound of steam at 165 lb. pressure).

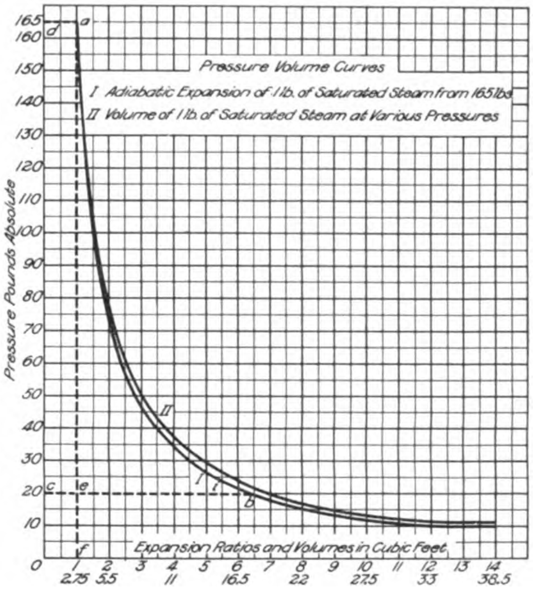


Fig. 2

$$23760 \times (2.751 - 0.016) = 64980 \text{ ft. lbs.} = 836 \text{ B.t.u.}$$

This is the heat equivalent of *this part* of the heat of vaporization. Since we are considering the available energy between 165 lb. and 20 lb., the small area e c o f must be deducted, and our work diagram only include the rectangle a e c d.

In practice the part of a pressure-volume, or "indicator" diagram, corresponding to the area a e c d is produced in a cylinder before cut off; but it is clear that the same theoretical conditions exist if we imagine a pound of water vaporized within the cylinder itself, doing the work necessary for its natural increased displacement as a saturated vapor while boiling to the condition of steam.

(*To be Continued*)

INSTALLATION AND OPERATION OF SWITCHBOARDS

By S. W. Mauger

After a switchboard has been designed, the next important steps towards getting it in shape for operation are: construction in factory, packing for shipment, unpacking at destination, and the final setting up. The last two steps are not by any means the least important for being at the end of the list.

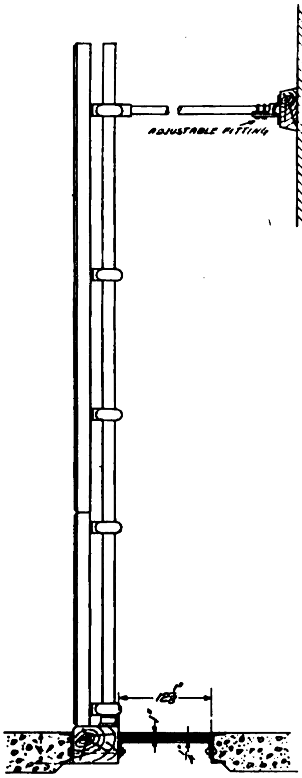


Fig. 1. Panel with Pipe Supports, Showing Wood Sill and Slate Covered Cable Slot

It will be assumed in this article that the switchboard has been properly designed, built and packed; that it has been taken from the cars at its destination, and is ready for unpacking. Great care should be exercised in this operation; first, that nothing may be broken or marred; and, second, that no screws, bolts or other parts are left in the packing material and thrown away. After the parts have been unpacked they should be looked over carefully to see that no foreign material has lodged in holes, pockets or crevices of the apparatus, and that no parts are in any way injured. Such parts as will not be required immediately should be grouped together and put away in an orderly manner, and if possible in a dry place, out of the reach of people who have no responsibility as to the setting up of the switchboard. This seemingly unimportant advice will be found useful some time or other, and will save considerable delay, expense and inconvenience if followed carefully.

It is, of course, assumed that a place has been previously selected for the location of the switchboard. To be suitable, this should be chosen so as to meet the following requirements.

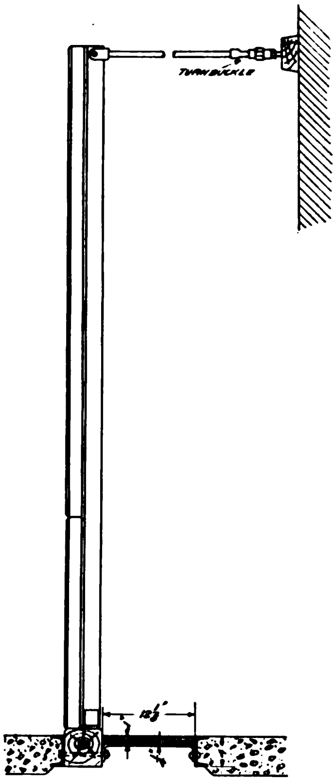


Fig. 2. Panel with Angle on T-Iron Supports, Showing Wood Sill and Slate Covered Cable Slot

1. Ample space must be provided in front and back of switchboard, so that the operator

will have plenty of room and there will be no necessity of crowding the switchboard.

2. Allowance should be provided, such that extensions may be made in the most convenient manner, both as regards the switchboard itself, and the wiring to the machines and feeders.

3. Switchboard should be placed where the operator will have a commanding view of the station. (This applies, of course, only to that part of the switchboard containing the instruments and controlling switches, or handles of switches, etc.)

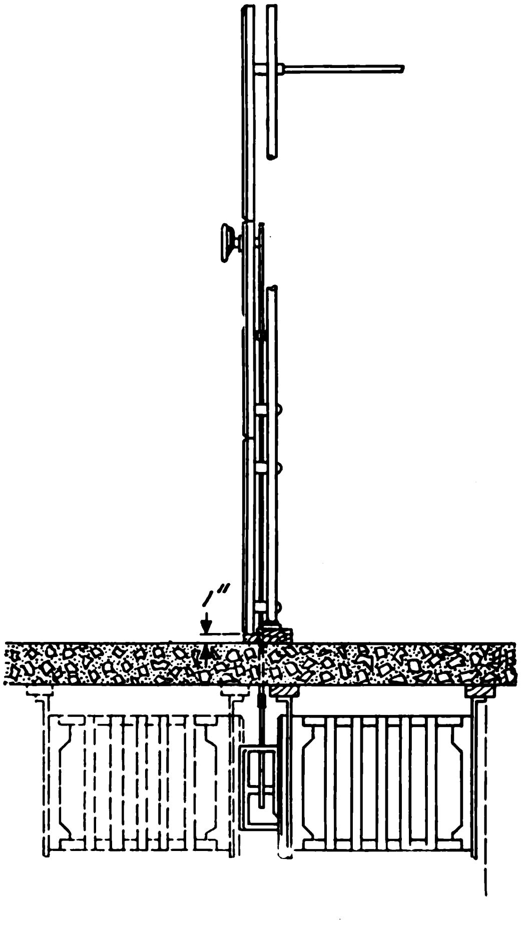


Fig. 3. Rheostats Arranged Under Flooring. Panel Resting on Wood Sill without Cable Slots. Floor Bushings used for Cables

4. If electrically operated switches are used, they will not necessarily be placed near the controlling board, but should usually be placed with regard to convenience of connections and safety from fire and in handling.

The switchboard should stand on a level foundation, which may be made of hard wood, or iron in the form of "I" or channel beams. When the switchboard is for a system, one side of which is grounded, it is recommended that the panel supports be insulated from "ground," in which case a wood sill projection one or two inches above the floor makes the most suitable foundation. When the panel supports are "grounded" an iron foundation may be used, although in any case the wood foundation is the simpler.

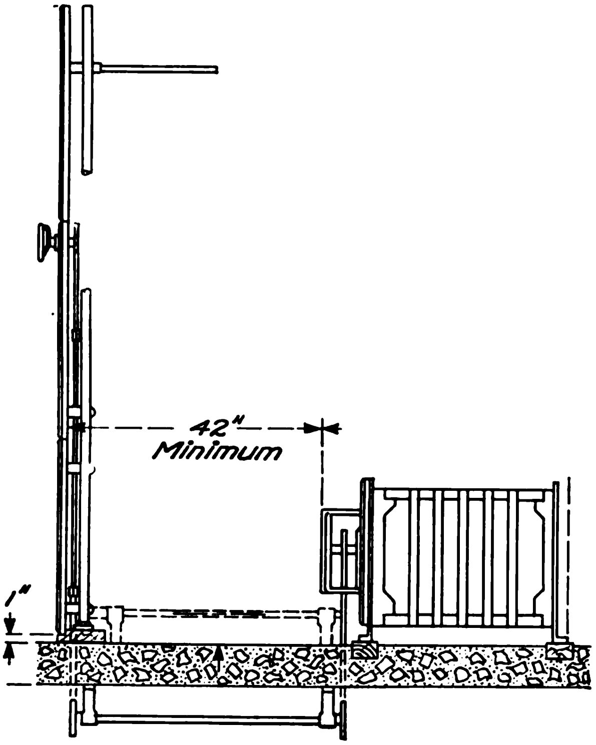


Fig. 4. Rheostats Arranged Back of Board. Panel Resting on Wood Sill without Cable Slots. Floor Bushings used for Cables

Everything being now provided, work can proceed on the setting up of the switchboard. The first thing to be done is to put the switchboard supports or framework into place; but the parts should not be rigidly bolted together until after the panels are in place and properly lined up. The next thing, of course, is to set up the panels in their proper places, bolting them loosely to the supporting irons. After all the panels are placed and adjusted, the bolts can be tightened, and the different devices which have been shipped separately, placed on their respective panels.

The reason for bolting loosely at first is to avoid cracking the marble or slate. as these materials have no flexibility and are comparatively brittle. With all clamping bolts, thin paper or fiber washers should be used between panels and iron work.

Figs. 1, 2, 3 and 4 show suitable methods of mounting and supporting switchboards.

The connections should be assembled on the backs of the panels, carefully consulting the switchboard drawings to see that everything is in its proper place. All wiring should be done in a neat and safe manner. Special attention should be given to joints, whether bolted joints of copper bars, or soldered or clamped joints of wires. All parts that are to form joints should be perfectly clean, bright, and free from burrs. Nuts on current-carrying studs should be securely screwed against connection bars or terminal lugs in order to get as good contact as possible. Much trouble from over-heating may be caused by a loose connection.

When installing high tension switchboards there are many other details to be considered, a few of them being: the mounting of instrument transformers; the running of secondary instrument leads; the running of main high tension leads so as to obtain proper distances from each other and from ground and the suitable taping of joints; the building of switch and bus bar compartments in large stations, etc.

The following table gives the recommended spacing for alternating current conductors:

Volts	CLEARANCE BETWEEN CONDUCTORS OF OPPOSITE POLARITY		CLEARANCE TO GROUND	
	Min.	Preferred	Over Smooth Dry Surface	In Air
2500	5"	6"	3 to 4"	* 3 to 4"
7500	6"	8"	6"	* 4"
15000	9"	12"	8"	4"
22000	14"	18"	12"	6"
35000	18"	24"	20"	10"
45000	24"	30"	26"	13"
70000	30"	36"	36"	18"
110000	48"	60"	60"	30"

* Principally for mechanical reasons.

For voltages up to 22000 volts, where insulated wire is used, the clearances may be reduced, say, 33⅓ per cent. for wires not connected to buses.

The above table, of course, does not hold for wire run in duct or pipe, nor for lead covered nor multiple conductor cable.

Avoid, as much as possible, sharp turns, corners or edges.

In order to avoid "corona effects" on high tension conductors, the following minimum sizes should be used:

Volts	Size B & S
35000	No. 12
45000	No. 10
70000	No. 8
110000	No. 2

It may be advisable in some cases to increase the sizes for mechanical reasons.

In running low tension A.C. conductors carrying current above 2000 amperes, close proximity to iron work or sensitive instruments should be avoided; otherwise the iron work will overheat, and the instruments may be rendered inaccurate. With large current capacities it is not advisable to operate at as high a current density as that employed with the smaller capacities; in fact, for capacities of 6000 amperes and above, it is necessary to resort to special construction to overcome the heating from "skin effect." For this purpose hollow conductors, or cable with rope centers for increasing the diameter, are employed, as well as the inter-leaving of the conductors of the different phases.

It is not always convenient or advisable to mount current or potential transformers on the back of panel, and they should then be located with respect to convenience of wiring, accessibility and safety. The best location may be under the floor, or on the wall or a framework; but this must be determined for each particular case.

The leads from the instrument transformers to the switchboard should preferably be of the double or multiple conductor type; or if single conductors are used, they should be run close together to avoid induction. For long distances the leads may be lead covered, or simply rubber covered and run in pipe conduit, the latter being the usual practice.

The main switchboard wiring should be carried on suitable insulators, securely mounted on rigid supports. It should be the aim to obtain accessibility, and to avoid the danger of trouble occurring on one conductor involving other conductors. All cable or wire joints should be safely and neatly taped, or covered in some other equally suitable manner. When buses are carried in compartments they may be bare, relying on safe

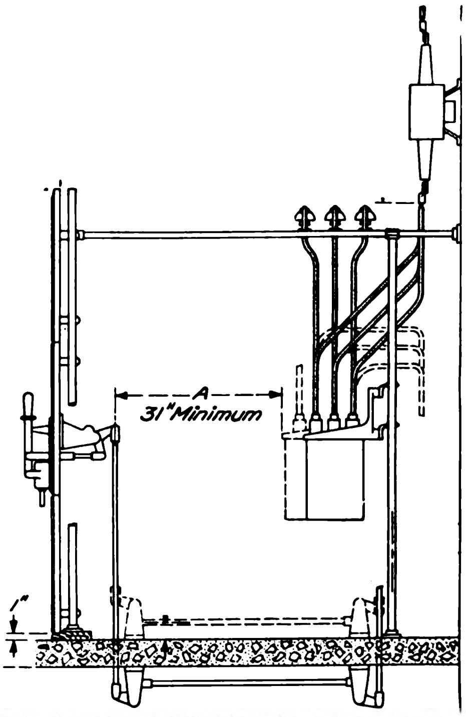


Fig. 5. Arrangement of Oil Switches on Pipe Framework for Voltages up to and Including 6600 Volts

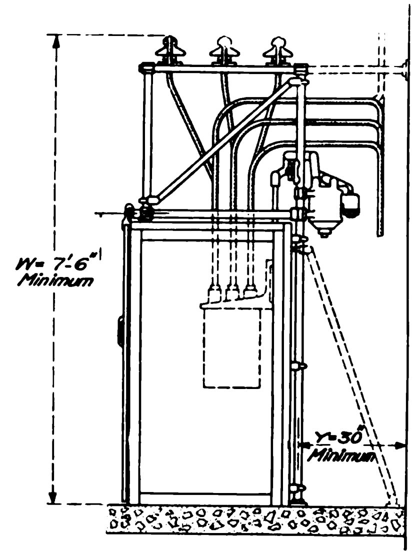


Fig. 8. Arrangement of Oil Switches Mounted on Asbestos Board Cells, for Voltages up to and Including 15,000 Volts

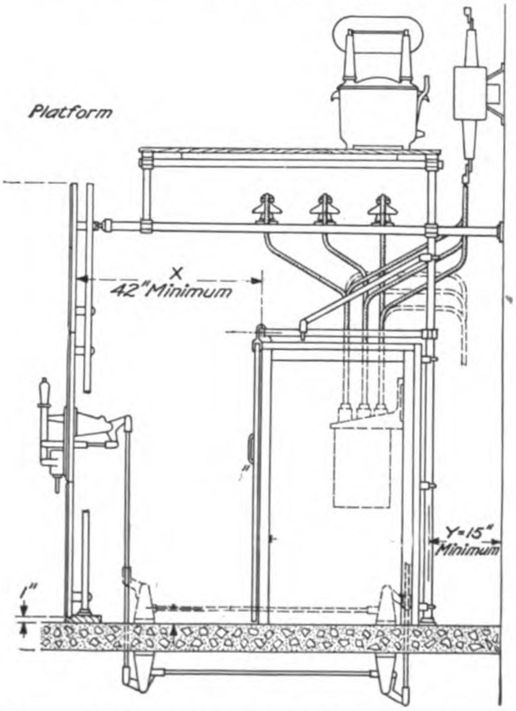


Fig. 6. Arrangement of Oil Switches Mounted on Asbestos Board Cells, for Voltages up to and Including 15,000 Volts

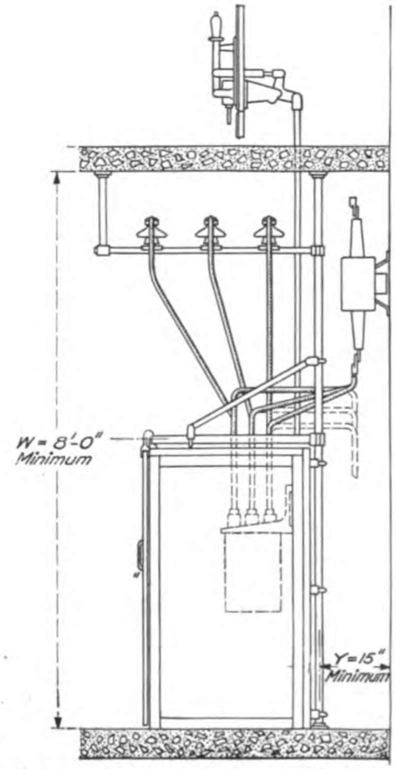


Fig. 7. Arrangement of Oil Switches Mounted on Asbestos Board Cells, for Voltages up to and Including 15,000 Volts

distances and suitable insulators for protection. In building compartments, arrangements should be made so that the joints are accessible for inspection and for such work as may be necessary from time to time. It should be borne in mind that the buses are an all-important part of an installation, carrying as they do the whole energy of the plant in a confined space, and making it essential to use extreme care both in selecting the proper materials and in workmanship. The connections between switches and buses are practically part of the buses, and should be as safely installed. The exact details of design cannot be determined without knowing conditions, but Figs. 5 to 18 show methods that have been successfully employed.

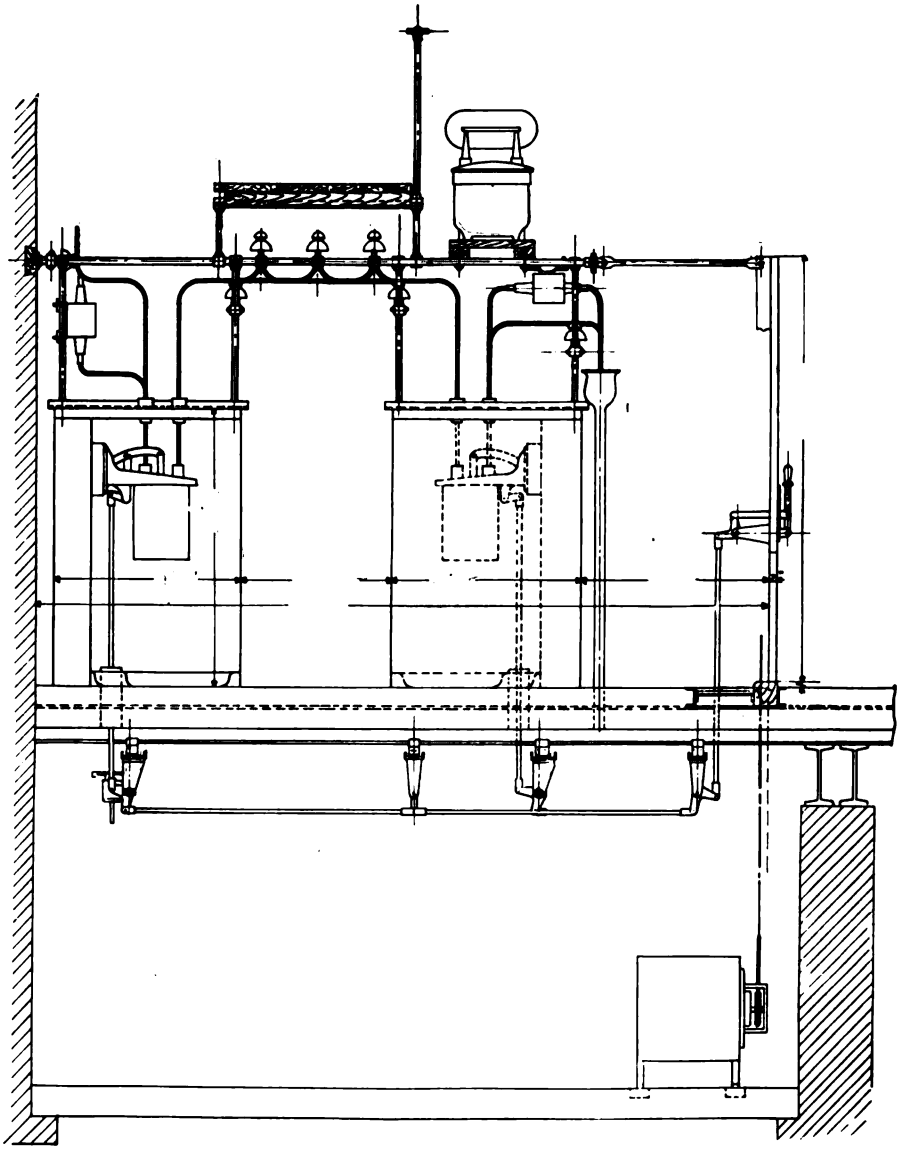


Fig. 9. Arrangement of Hand Operated Oil Switches in Brick or Concrete Cells

The switch compartments must be determined by the type of switch used, and should be built according to the recommendations of the manufacturer furnishing the switches. There have been various materials used for bus bar and switch compartments; namely, brick, concrete, soapstone and slate, and usually a combination of brick with one of the other materials. Sometimes the entire compartments are built of concrete, which makes good construction when those doing the work are familiar with the characteristics of concrete. When brick is employed, it is recommended that cement mortar be used. Of late, cells have been made of asbestos board, with pipe framework to support the weight of oil switches. (See Figs. 6, 7 and 8.)

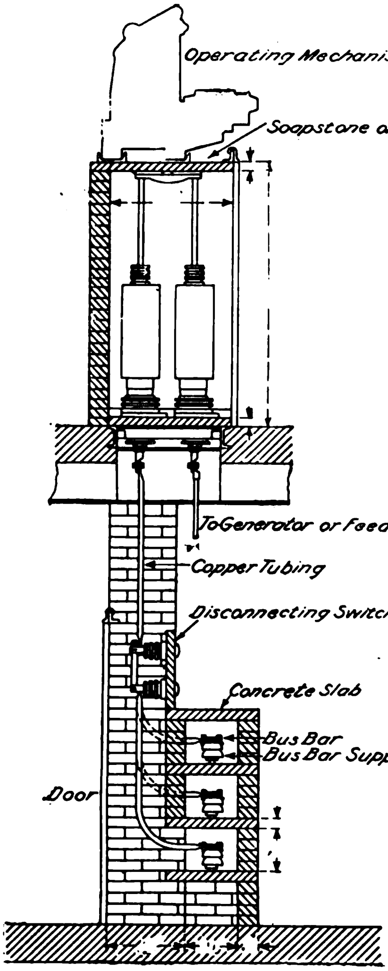


Fig. 10 A Typical Arrangement of 13,200 Volt Bus Bars, Electrically Operated Oil Switches, and Disconnecting Switches in Three Phase Stations

Removable doors are recommended for all openings of compartments, to prevent accidental contact with live parts; and in the case of oil switches, to prevent the scattering of oil, should oil be forced out of the oil pots. Doors have been made of sheet iron, wood covered with asbestos, soapstone, and asbestos pressboard with wood or iron frame. Doors for oil switch compartments should be made of light fireproof material, and swung from the top to allow their free movement in cases of explosion in the compartments. If made of heavy material, or fastened solidly to the compartments, they are liable to be blown off and do considerable damage. Asbestos lumber with light wood frame has proved the most satisfactory construction for oil switch doors.

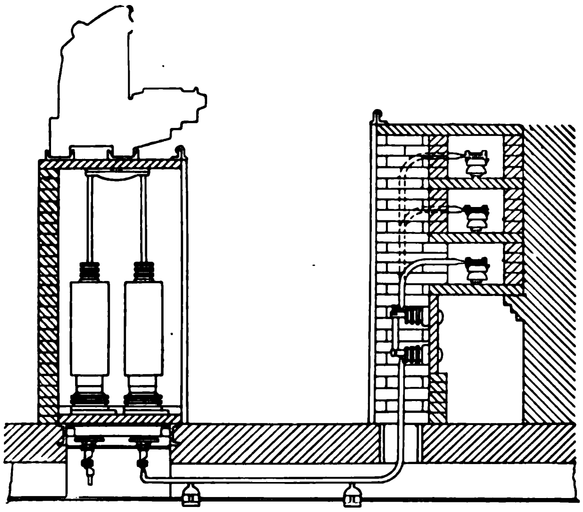


Fig. 11. Another Typical Arrangement of 13,200 Volt Bus Bars, Electrically Operated Oil Switches, and Disconnecting Switches in Three Phase Stations

Operation

Before putting a switchboard in service, all connections should be tested to see that there are no open or short circuits. Connections to instruments, meters, relays, etc., should be carefully traced, and preliminary trial made to see that ammeters, voltmeters, wattmeters, etc., read or record in the proper direction. In fact, before putting a switchboard into actual service, it is advisable to put current through all parts, at reduced voltage in order to bring out any weak spots. This may be accomplished by providing an artificial load consisting of a water rheostat, or by short circuiting the bus bars, giving the generator only enough field to obtain full load armature current. It is also recommended in connection with large installations of high voltage—say 2300 volts and above—to give the wiring a high potential test of at least double the normal voltage, lasting about one minute.

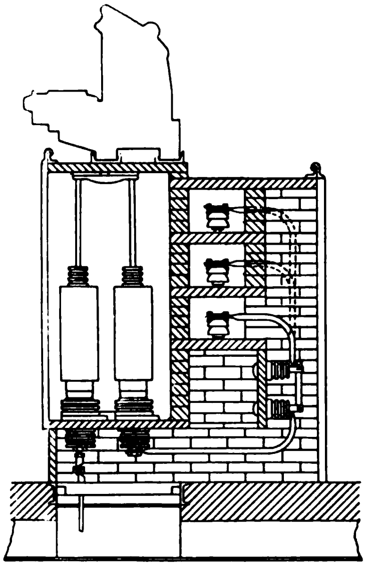


Fig. 12. Arrangement Similar to that of Fig. 11, Though More Compact

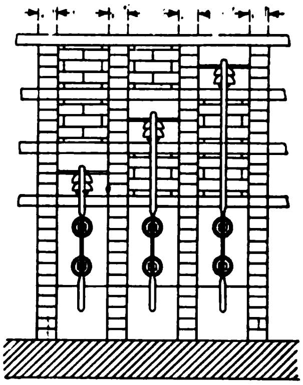


Fig. 12-A. Front View of Bus Compartments of Figs. 10, 11 and 12

When everything is found to be in proper condition, the switchboard should be turned over to the operating engineer, for operation under actual service conditions. At first, every detail should be closely watched, all phenomena out of the ordinary carefully noted, and an investigation made to determine their causes. In this way the weak spots can be located and seen to and much future trouble avoided. By this it is not meant that no care should be exercised after the switchboard has been in operation for a while. On the contrary, regular inspection of all parts is absolutely essential to successful operation. This is especially true in regard to apparatus that has moving parts. Attention should be given to joints in cable, buses, connection bars and current carrying studs; and to temperature, insulation, cleanliness, etc. In making an inspection, or repairing work near live parts, care should be exercised to avoid accidentally short circuiting or grounding the connections. In connection with switchboards for voltages of 1000 volts and above, it is recommended, where possible, to make the parts dead before working on them. If this is not done, considerable risk is incurred. Of course, other precautions can be taken, such as using rubber gloves, insulating platform, etc., but these only partially offset the risk; in fact, it would be absolutely foolhardy to rely on such precautions on voltages above 3500 volts.

In circuits of over 600 volts, do not consider any device used therein safe to touch unless the manufacturers allow the grounding of the device, and suitable ground connection has been made. This applies to instruments connected directly to high tension circuits, current transformers, etc.

Placing in a list the most important duties of the operator, we would have the following directions:

(1) Before each starting of the plant, be sure that no switches or circuit breakers are closed, and that no other device is in such condition as to cause trouble when throwing voltage on the panels.

(2) After everything is adjusted and running, take frequent readings of instruments to see that no device is overloaded to a dangerous point. This would cover wires as well as switches and instruments.

(3) Make occasional but regular tests of instruments and meters, to determine any inaccuracies, at the same time noting any parts that need repairing.

(4) Regularly inspect switches, circuit breakers and relays, to see that contacts are in good shape and that there is no sticking. If oil switches are used, see that there is sufficient oil in the pots, but not too much, and that it is not badly carbonized. It is well to regularly inspect oil switches, say every 3 to 6 months, and also to inspect each switch directly after it has opened on short circuit or severe overload. In fact, as a matter of precaution, it is well to change the oil after each short circuit or severe overload, changing the oil after regular inspection only when it appears to be badly carbonized. Oil taken out of oil switches may be filtered and used again. Use no oil except that which is recommended by the switch manufacturers.

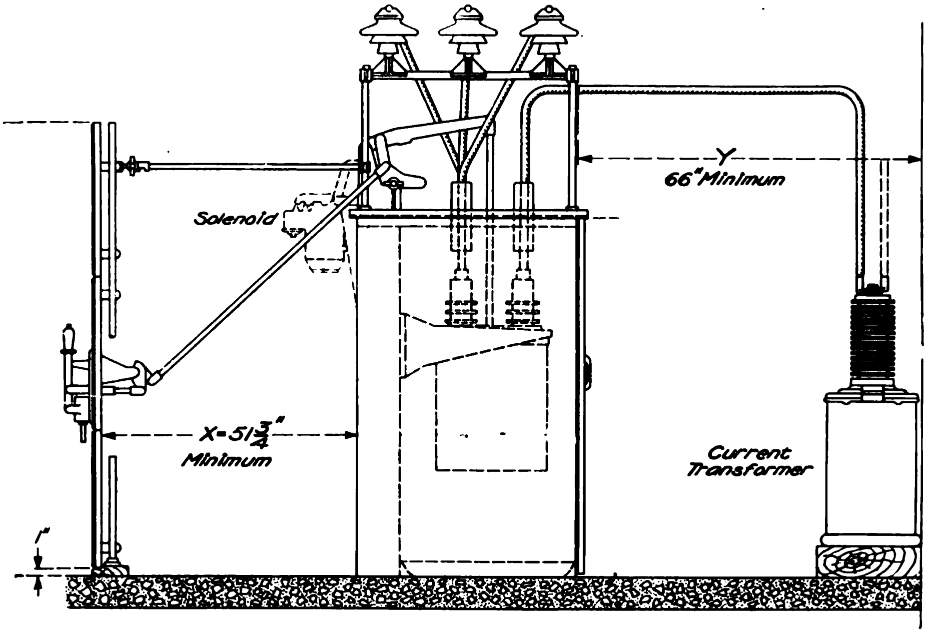


Fig. 13. Arrangement of Three Single Pole 45,000 Volt Oil Switches in Brick or Concrete Cells

If magnetic blowout circuit breakers are installed, see that blowout chutes are clean and that secondary contacts are properly adjusted according to the manufacturer's instructions.

If circuit breakers or switches with carbon or other secondary contacts are furnished, see that the secondary contacts are in good shape and properly adjusted so that they will take the final break and prevent arcing on the main contact. Also, see that there is sufficient contact between the main brush and contact block.

(5) Regularly inspect the back of the panels, and keep all joints in good condition.

(6) Regularly clean the switchboard, especially in buildings where there are inflammable particles flying around. In cleaning the back of the board, compressed air applied through a nozzle by means of flexible hose is the simplest and safest method. Failing this, a hand bellows may be used. Wiping is not recommended back of the board, although this method of cleaning may be employed on instruments on front of board when they are not directly connected to high tension circuits.

(7) When knife switches are used in series with circuit breakers of the carbon break or magnetic blowout type, the circuit breaker should be closed or opened before the knife switches, when closing or opening the circuit. When closing the switches, it is well to turn the face away from the switchboard to avoid having the eyes "flashed" in case there is a short circuit on the line and the circuit breaker should open.

(8) When knife switches are used in series with oil switches on A.C. circuits, the knife switches should *never* be opened until after the oil switches are opened; but the knife switches should always be closed before the oil switches. Hand-operated oil switches with automatic attachment, if properly designed, are arranged so that it is impossible to keep the switches closed in case of trouble, such as a short circuit on the line.

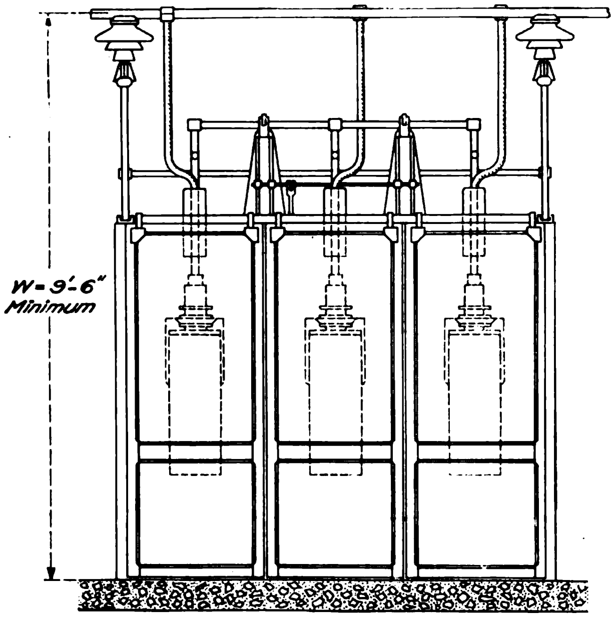


Fig. 14. Arrangement of Three Single Pole 45,000 Volt Oil Switches in Brick or Concrete Cells. Front View

A practical operator will lay out for himself a regular routine, which will vary with the type of the plant and the design of switchboard devices used. The above items will cover in general the routine to be followed; but it is obvious that details given for a D.C. railway plant, for example, would not apply for a 10000 volt A.C. power plant.

When operating machines in multiple, there are a few other points to be noted, which may be covered as follows:

(1) When D.C. shunt wound machines are to be operated in parallel, in order to connect a machine to the bus bars after one machine is already connected, all that is necessary before closing the switch is to see that the voltage of the machine being connected is of the same magnitude as that of the bus bars, and that similar poles are connected.

(2) In operating D.C. compound wound generators of small size, where a three-pole main switch is used (thus making the equalizer connections at the same time as the main connections), the instructions given for shunt wound machines will apply.

(3) In operating large D.C. compound wound generators, or where separate switches are provided for equalizer connections and each main connection, the equalizer switch and the main switch on the same side of the generator as the equalizer switch should be closed first, to excite the series field. The voltage of the machine should be adjusted to the voltage of machines already connected to the bus bars; the circuit breaker (if any) in the side of the machine opposite the series field should then be closed; and lastly, the switch in series with the circuit breaker.

(4) If machines are provided with field switches, they should be closed before the main switch is closed, and opened after the main switch is opened.

(5) In operating A.C. generators in parallel, the rule given for shunt wound D.C. machines will apply, with the additional operation, before closing the main switch, of synchronizing. This term is applied to the operation necessary to ascertain when the machines to be run together have the same speed and phase rotation; that is, when the corresponding conductors of the machines to be connected together coincide as to angular motion and position.

Different methods of synchronizing are employed, some of which use incandescent lamps, and others, a voltmeter or a special instrument designed to indicate synchronism, called a synchronism indicator, or synchroscope. Practically all plants now use the special instrument. In using this synchronism indicator, the operator must become accustomed to the time element of the generator switch, so as to close the switch when the needle is at the proper point on the dial. There is considerable difference in the time required to close different switches, and this must be taken into consideration. In the case of solenoid operated switches using current the voltage of which varies, the time required to close will vary with the voltage, and due allowance must be made therefor. A heavy strain is put upon the switches and generators if the generators are out of synchronism when the switch is closed, and for this reason the behavior of switches and machines should be carefully noted during the process of putting a generator into service in parallel with other generators. After a few operations of synchronizing, the operator, if he has made close observation, should be able to readily determine when to close the switch. In general, it may be said: Do not close the generator switch if the synchronism indicator needle is travelling too fast, or if it is travelling away from the "zero" point.

After a direct or alternating current machine has been connected to the bus bars in parallel with other machines, it becomes necessary to adjust the fields so that all machines divide the load proportionately, at the same time seeing that the prime movers are adjusted to the proper speed.

VARIABLE RATIO CONVERTERS

("Split Pole" Converters)

PART II

By Chas. P. Steinmetz

Variable Ratio by Change of Wave Shape of the Y Voltage.

If, in the converter shown diagrammatically in Fig. 10, the magnetic flux disposition and the pitch of the armature winding are such that the potential difference between the point *a* of the armature and the neutral 0, or Y voltage, is a sine wave (Fig. 11A), then the voltage ratio is normal. Assume, however, that the voltage curve *a* differs from sine shape, due to the superposition of some higher harmonics; namely, the third harmonic in Fig. 11, B and C, and the fifth harmonic in Fig. 11, D and E. Then, if these higher harmonics are in phase with the fundamental, as in Fig. 11, B and D, they increase the maximum of the alternating voltage, and thereby the direct current voltage; but if these harmonics are in opposition to the fundamental, as in Fig. 11, C and E, they decrease the maximum alternating voltage, and thereby the direct current voltage, without appreciably affecting the effective value of the alternating voltage. For instance, a higher harmonic of 30 per cent. of the fundamental increases or decreases the direct current voltage by 30 per cent., but varies the effective alternating voltage by only

$$\sqrt{1 + .3^2} = 1.044, \text{ or } 4.4 \text{ per cent.}$$

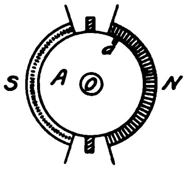


Fig. 10

The superposition of higher harmonics therefore offers a means of increasing as well as decreasing the direct current voltage with constant alternating voltage, without change of angle between brush position and resultant magnetic flux.

However, as the terminal voltage of the converter does not depend only on the induced e.m.f. of the converter, but also on that of the generator, and is a resultant of the two e.m.f's. in approximately inverse proportion to the impedances from the converter terminals to the two respective induced e.m.f's., only such higher harmonics may be used for

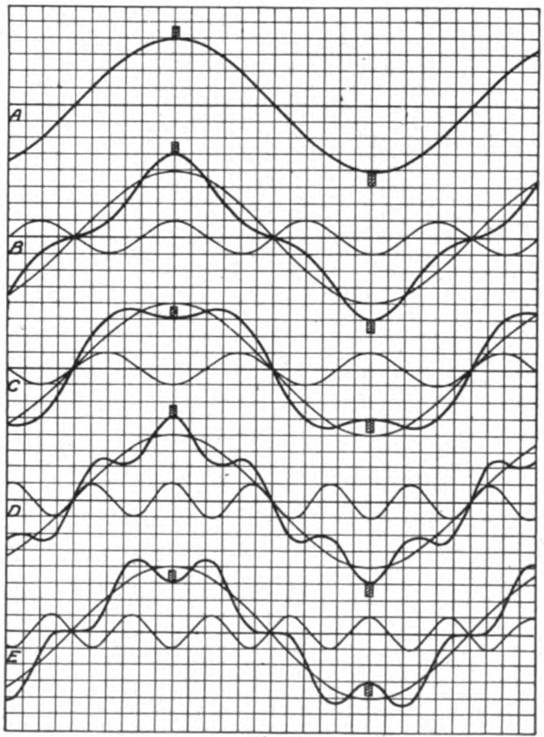


Fig. 11

varying the converter ratio as can exist in the Y voltage without appearing in the converter terminal voltage, or supply voltage.

In general, in an n phase system, an nth harmonic existing in the star, or Y voltage, does not appear in the ring or delta voltage, as the ring voltage is the combination of two star voltages displaced in phase by $\frac{180}{n}$ degrees for the fundamental, and therefore by 180 degrees, or in opposition, for the nth harmonic.

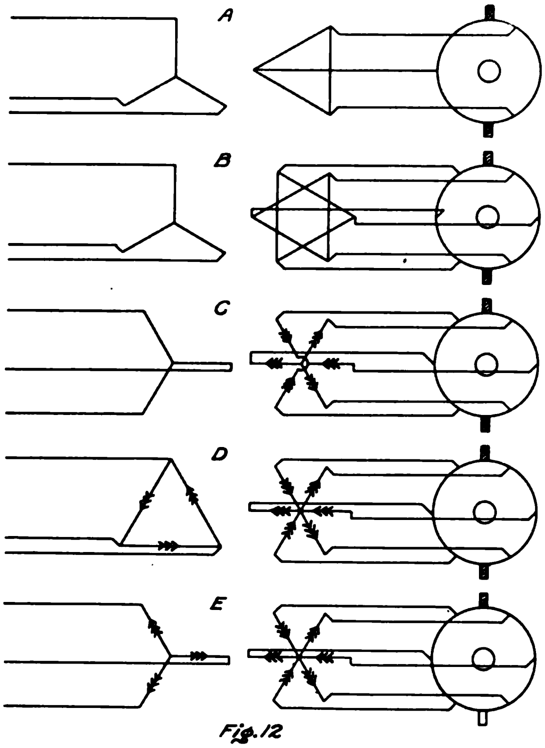


Fig. 12

Thus, in a three phase system, the third harmonic can be introduced into the Y voltage of the converter, as in Fig. 11, B and C, without affecting or appearing in the delta voltage, and can therefore be used for varying the direct current voltage; whereas the fifth harmonic can not be used in this way, since it will reappear and cause a short circuit current in the supply voltage. Hence the latter harmonic should be made sufficiently small to be harmless.

The third harmonic can be used for varying the direct current voltage in the three phase converter diagrammatically shown in Fig. 12A; and also in the six phase converter with double delta connection, shown in Fig. 12B, and double Y connection, shown in Fig. 12C, since these consist of two separate three phase triangles of voltage supply, neither of them containing the third harmonic. In such a six phase converter with double Y connection (Fig. 12C), the two neutrals, however, must not be connected together, as the third harmonic voltage exists between the neutrals. In the six phase converter with diametrical connection, the third harmonic of the Y voltage appears in the terminal voltage, as the diametrical voltage is twice the Y voltage. In such a converter, if the primaries of the supply transformers are connected in delta, as in Fig. 12D, the third harmonic is short circuited in the primary voltage triangle, producing excessive currents which cause heating, and which interfere with the voltage regulation. This arrangement is therefore not permissible. If, however, the primaries are connected in Y, as in Fig. 12E, and either three separate single phase transformers, or a three phase transformer with three independent magnetic circuits, are used, as in Fig. 13, the triple frequency voltages in the primary are in phase with each other between the line and the neutral, and consequently cannot produce any current with an isolated neutral. With a three phase transformer such as is shown in Fig. 14, that is, one in which the magnetic circuit of the third harmonic is open, triple frequency currents can flow in the secondary, and this arrangement, therefore, is not satisfactory.

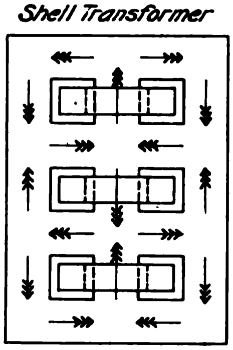

Shell Transformer

Fig. 13

In two phase converters, higher harmonics may be used for regulation only when the transformers are connected in such a manner that the regulating harmonic, which appears in the converter terminal voltage, does not appear in the transformer terminals; that is, by a connection analogous to Fig. 12E and Fig. 13.

As the direct current voltage regulation of a three phase or six phase converter of this type is produced by the third harmonic, the problem is to design the magnetic circuit of the converter so as to produce the maximum third harmonic, the minimum fifth, and the minimum seventh harmonic.

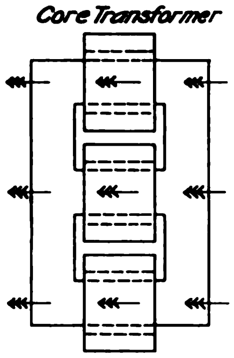


Fig. 14

If q = interpolar space, then $(1-q)$ = pole arc as fraction of pitch; and the wave shape of the voltage induced between the point a of a full pitch distributed winding (as generally used for commutating machines) and the neutral, or induced Y voltage of the system, is, when neglecting magnetic spread at the pole corners, a triangle with the top cut off for distance q, as shown in Fig. 15.

If, then, e_0 = voltage induced per ampere turn while the conductors are in front of the field pole (which is proportional to the magnetic density in the air gap), and m = series turns from brush to brush, the maximum voltage of the wave shown in Fig. 15, is:

$$E_0 = m\, e_0\, (1-q)$$

When developed into a Fourier series, the equation of the voltage wave a, Fig. 15, becomes:

$$e = \frac{8\, E_0}{(1-q)\pi^2} \sum_1^{\infty} n \frac{\cos \frac{(2\, n-1)}{2} q\pi}{(2n-1)^2} \cos\, (2n-1)\phi$$

or, substituting for E_0, and putting:

$$A = \frac{8\, m\, e_0}{\pi^2}$$

the equation becomes

$$e = A \sum_1^{\infty} n \frac{\cos \frac{2n-1}{2} q\pi}{(2n-1)^2} \cos\, (2n-1)\phi$$

$$= A \left\{ \cos q\frac{\pi}{2} \cos\, \phi + \frac{1}{9} \cos 3\, q\frac{\pi}{2} \cos\, 3\, \phi + \frac{1}{25} \cos 5\, q\frac{\pi}{2} \cos\, 5\, \phi + \frac{1}{49} \cos 7\, q\frac{\pi}{2} \cos\, 7\, \phi + \ldots \right\}$$

Thus the third harmonic is a positive maximum for $q = 0$, or 100 per cent. pole arc, and a negative maximum for $q = \frac{2}{3}$, or 33.3 per cent. pole arc.

For maximum direct current voltage, q should therefore be made as small as possible; that is, the pole arc should be made as large as commutation permits. In general, the minimum permissible value of q is about 0.15 to 0.20.

The fifth harmonic vanishes for $q = 0.20$ and $q = 0.60$, and the seventh harmonic for q = 0.143, 0.429 and 0.714.

For small values of q, the sum of the fifth and seventh harmonics is a minimum for about $q = 0.18$, or 82 per cent. pole arc.

When $q = 0.18$, or 82 per cent. pole arc:

$$e_1 = A \left\{ 0.960 \cos \phi + 0.0736 \cos 3\, \phi + 0.0062 \cos 5\, \phi - 0.0081 \cos\, 7\, \phi + \ldots \right\}$$

$$= 0.960\, A \left\{ \cos \phi + 0.0766 \cos 3\, \phi + 0.0065 \cos 5\, \phi - 0.0084 \cos 7\, \phi + \ldots \right\}$$

That is, the third harmonic is less than 8 per cent., so that not much voltage rise can be produced in this manner, while the fifth and seventh harmonics together are only 1.3 per cent., and therefore negligible.

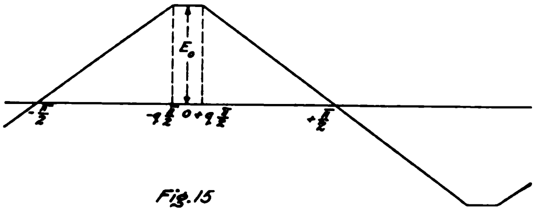


Fig. 15

Better results are given by reversing, or at least lowering the flux in the center of the field pole. Thus, dividing the pole face into three equal sections, the middle section, of 27 per cent. pole arc, gives the voltage curve:

$q = 0.73$

$$e_2 = A \left\{ 0.411 \cos \phi - 0.1062 \cos 3\, \phi + 0.0342 \cos 5\, \phi - 0.0035 \cos\, 7\, \phi \ldots \right\}$$

$$= 0.411\, A \left\{ \cos \phi - .258 \cos\, 3\, \phi + 0.083 \cos 5\, \phi - 0.0085 \cos\, 7\, \phi \ldots \right\}$$

The voltage curves resulting from reducing the pole center to one-half intensity, to zero, reversing it to half intensity, to full intensity, and to such intensity that the fundamental disappears, are given by:

$$
\begin{array}{llll}
(1) & \text{Full:} & e = e_1 = & .960\,A.\left\{ \cos\phi + .077\cos 3\phi + .0065\cos 5\phi - .0084\cos 7\phi \ldots \right\} \\
(2) & \tfrac{1}{2}: & e = e_1 - .5e_2 = & .755\,A.\left\{ \cos\phi + .168\cos 3\phi - .0144\cos 5\phi - .0085\cos 7\phi \ldots \right\} \\
(3) & 0: & e = e_1 - e_2 = & .549\,A\left\{ \cos\phi + .328\cos 3\phi - .053\cos 5\phi - .0084\cos 7\phi \ldots \right\} \\
(4) & -\tfrac{1}{2}: & e = e_1 - 1.5e_2 = & .344\,A\left\{ \cos\phi + .680\cos 3\phi - .131\cos 5\phi - .0084\cos 7\phi \ldots \right\} \\
(5) & -\text{Full:} & e = e_1 - 2e_2 = & .138\,A\left\{ \cos\phi + 2.07\cos 3\phi - .45\cos 5\phi - .008\cos 7\phi \ldots \right\} \\
(6) & -1.17: & e = e_1 - 2.34e_2 = & .322\,A\left\{ \cos 3\phi - .227\cos 5\phi \ldots \right\}
\end{array}
$$

It is interesting to note that in the last case the fundamental frequency disappears and the machine is therefore a generator of triple frequency, that is, it produces or consumes a frequency equal to three times synchronous frequency. The seventh harmonic also disappears in this case, and only the fifth is appreciable, and even this could be greatly reduced by a different kind of pole arc.

	Max. fundamental A.C. volts	D.C. volts
1	.960	1.033
2	.755	.883
3	.549	.743
4	.344	.578
5	.138	.423
6	0	.322
Normal	.960	.960

As seen, a considerable increase of direct current voltage beyond the normal ratio involves a sacrifice of output, due to the decrease or reversal of a part of the magnetic flux, whereby the air gap section is not fully utilized. Thus, it is not advisable to go too far in this direction.

By the superposition of the third harmonic upon the fundamental wave of the Y voltage, in a converter with three sections per pole, an increase of direct current voltage over normal voltage can be produced by lowering the excitation of the middle section and raising that of the outside sections of the field pole; inversely, a decrease of the direct current voltage below its normal value can be obtained by raising the excitation of the middle section and decreasing that of the outside sections of the field poles. In the latter case the voltage variation is effected by making the magnetic flux distribution peaked at the armature periphery, and in the former case, by making the flux distribution flat topped, or even double peaked.

Armature Reaction and Commutation

In such a converter, let p = ratio of direct current voltage to that voltage which the machine would have at normal voltage ratio with the same alternating impressed voltage, where $p > 1$ represents an over normal, $p < 1$ a subnormal direct current voltage. The direct current, and consequently the direct current armature reaction, is changed from the value which it would have at normal voltage ratio, by the factor $\frac{1}{p}$, since the product of direct current volts and amperes must be the same as at normal voltage ratio, being equal to the alternating power input minus losses.

With unity power factor, the direct current armature reaction F in a converter of normal voltage ratio is equal and opposite to the alternating current armature reaction F_0, and is neutralized thereby; but at a change of voltage ratio from normal, by factor p (thus changing the direct current by factor $\frac{1}{p}$), the direct current armature reaction is:

$$F = \frac{F_0}{p}$$

hence leaving an uncompensated resultant.

In this type of converter, the brushes stand at the magnetic neutral, or at right angles to the magnetic flux, and since the alternating armature reaction at unity power factor is in quadrature with the magnetic flux, and the direct current armature reaction in line with the brushes, the two armature reactions are in the same direction and in opposition to each other, and therefore leave a resultant, in the direction of the commutator brushes, equal to

$$
\begin{aligned}
F' &= F - F_0 \\
&= F\,(1 - p)
\end{aligned}
$$

Consequently, the converter has an armature reaction proportional to the deviation of the voltage ratio from normal.

If $p > 1$, or above normal direct current voltage, the armature reaction is negative, or motor reaction, and the magnetic flux produced by it at the commutator brushes is therefore a commutating flux. If $p < 1$, or subnormal direct current voltage, the armature reaction is positive, or the same as in a direct current generator, though less in intensity; and the magnetic flux due thereto tends to impair commutation. In a direct current generator, by shifting the brushes to the edge of the field poles, the field flux is used as reversing flux to give commutation. In this converter, however, decrease of direct current voltage is produced by lowering the density of the outside sections of the field poles, and, with a considerable decrease of voltage below normal, the edge of the field may not have a sufficient flux density to give commutation. Therefore, either a separate commutating pole is required, or, what is preferable, the use of this type of converter only for raising the voltage; while for lowering the voltage, the other type, which operates by a shift of the resultant flux, giving a component of the main field flux as commutating flux, should be used.

With a polar construction consisting of three sections, this can be done by having the middle section at low excitation and the outside sections at high excitation, for maximum voltage. Then, to decrease the voltage, the excitation of the center section should be raised; but instead of lowering both outside sections, the section in the direction of the armature rotation should be left unchanged, the other outside section being lowered twice as much, thereby producing, in addition to the change of wave shape, a shift of the flux, as represented by the scheme of Fig. 16:

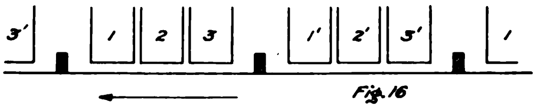


Fig. 16

Magnetic Density

Pole section:	1	2	3	1′	2′	3′
Maximum voltage:	$+B$	0	$+B$	$-B$	0	$-B$
	$+\frac{2}{3}B$	$+\frac{1}{3}B$	$+B$	$-\frac{2}{3}B$	$-\frac{1}{3}B$	$-B$
	$+\frac{1}{3}B$	$+\frac{2}{3}B$	$+B$	$-\frac{1}{3}B$	$-\frac{2}{3}B$	$-B$
	0	$+B$	$+B$	0	$-B$	$-B$
Minimum voltage:	$-\frac{1}{3}B$	$+1\frac{1}{3}B$	$+B$	$+\frac{1}{3}B$	$-1\frac{1}{3}B$	$-B$

Where the required voltage range above normal is not greater than that which can be produced by the third harmonic of a large pole arc with uniform density, this combination of voltage regulation by both methods can be carried out with two sections of the field poles, of which the one (towards which the armature moves) is greater than the other, as shown in Fig. 17. The variation is then as follows:

Pole section:	1	2	1′	2′
Maximum voltage:	$+B$	$+B$	$-B$	$-B$
	$+\frac{1}{2}B$	$+1\frac{1}{4}B$	$-\frac{1}{2}B$	$-1\frac{1}{4}B$
	0	$1\frac{1}{2}B$	0	$-1\frac{1}{2}B$
Minimum voltage:	$-\frac{1}{2}B$	$+1\frac{3}{4}B$	$+\frac{1}{2}B$	$-1\frac{3}{4}B$

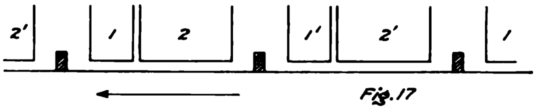


Fig. 17

The distribution of current in the armature conductors of the variable ratio converter, the wave form of the actual or differential current flowing in the conductors, and the effect of the wattless current thereon, are determined in the same manner as in the standard converter, and from them is calculated the local heating in the individual armature turns, and the mean armature heating.

The results in general are the same, showing a superiority of the six phase over the quarter phase, and of the quarter phase over the three phase arrangement. As regards the rating of the machine, based on armature heating, the variable ratio converter is intermediate between the standard converter and the direct current generator, approaching the former as the voltage ratio approaches normal. Therefore, the rating of such a converter, of constant direct current voltage differing from that corresponding to the alternating supply voltage, is far higher, and the size much smaller than that of a direct current generator.

Where, however, the converter is intended for operation over a considerable voltage range, as when connecting a storage battery to an alternating current system, the size of the converter is greater than that of a converter operating at constant voltage, by the same amount and in the same way as in the case of any apparatus intended for operation over a considerable voltage range. In other words, the magnetic circuit of the machine must be ample to carry the magnetic flux of maximum voltage, while the conductor section and commutator size must be sufficient for maximum current. This increase of size is a necessary result of operation over a voltage range, irrespective of the method by which the change of voltage is brought about, whether by a change of the converter ratio or otherwise, and consequently has nothing to do with the *method* of voltage regulation.

(To be Continued)

ELECTRIC ANNEALING AND TEMPERING FURNACES

By J. E. Kearns

For a long time tool producers and other manufacturing concerns whose products require tempering have hoped that some sort of a hardening furnace would be designed that might assure them better results in a shorter time than is possible by the present method of gas furnace annealing. Their hopes have at last been realized with the introduction of annealing by means of electricity.

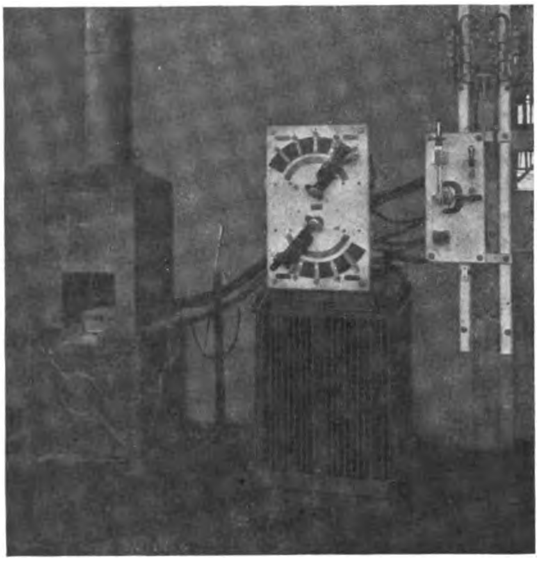


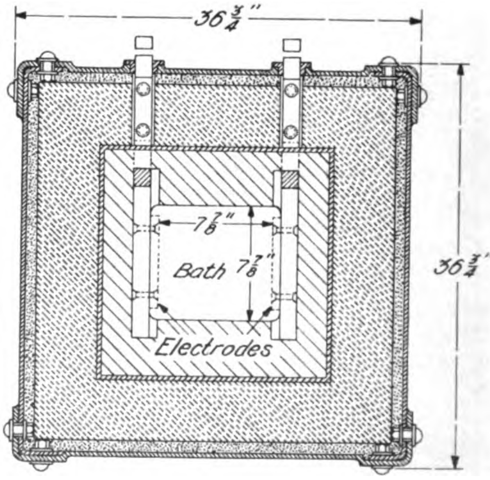
Fig. 1. Electric Annealing Furnace and Regulating Transformer

To attain the best results in the process of annealing and hardening, it is necessary to have a constant temperature in the furnace. The coal and gas furnaces of to-day by no means fulfill this requirement, on account of the large furnace area exposed to the air for radiation. Again, to obtain the best results, it is often necessary to adjust the temperature of the furnace, and this cannot be done with any precision with the gas furnace.

Ordinary steel tempering furnaces may be classified into two groups; first, that type of furnace in which the steel is placed into the heating material; and the second, that in which the steel does not come in direct contact with heating material. Under the first group come open fires, such as the ordinary forge and the furnaces having either natural or forced ventilation; while under the second class we include muffled furnaces of various designs.

With the new type of electric furnace which the General Electric Company is now building, metallic salts are reduced to liquid state by means of electricity. It can be easily seen that as soon as these salts reach a liquid condition the temperature can readily be regulated by the amount of current that is put through the bath, a fact which enables the operator to secure any temperature from 250 to 1350 degrees Centigrade. This temperature will remain uniform throughout the bath except at the surface, where, due to radiation, it is slightly lower, and this applies only to a depth of about 0.6 to 0.75 inches.

The illustration (Fig. 1) shows the furnace outfit as it is installed in the die department of the Schenectady Works, where it has been in practical service for several months.



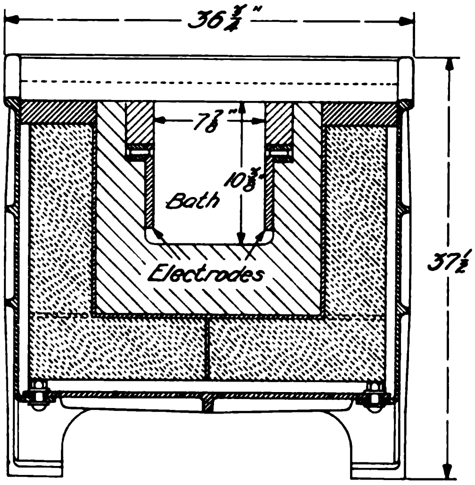
Sectional Plan of Furnace

The outfit, as can be seen, consists of the furnace, with its hood suspended from above; the regulating transformer, with regulating switch connected to the primary coil; the switchboard, which will contain the necessary ammeter and voltmeter; and the incoming line with fuses and throw over switch which is connected to the secondary winding of the transformer. The regulating switch will be provided with a sufficient number of contact points to insure almost any desired temperature from 250 to 1350 degrees Centigrade.

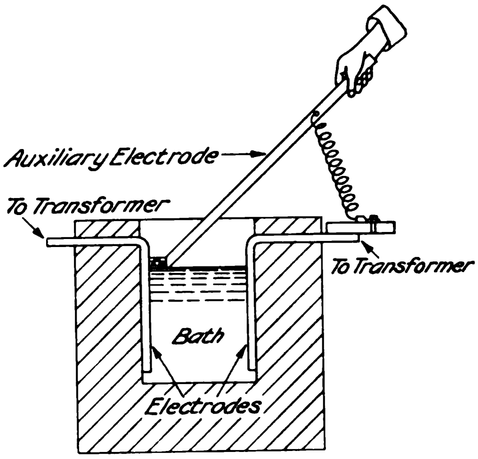
The furnaces, the general plans and section of which are shown herein, consist of a fire clay crucible surrounded by an insulating material, usually of asbestos, which rests in a fire clay box; all being held in by an iron supporting case. Two suitable electrodes are placed on each side of the crucible, and are in direct contact with the metal bath at all times.

To start up the furnace all that is necessary is to place some of the old broken flux between the electrodes and cover this with a little barium chloride; after which a small piece of carbon is pressed tightly against one of the electrodes by the auxiliary electrode; this produces an electric arc, and in a remarkably short time the solid mass is converted into a molten condition.

After the bath has reached its proper temperature, that portion of the material which is to be hardened is placed entirely in the liquid bath and is allowed to remain there until it attains the same color as the bath, when it is removed and placed in water or oil, as required, to temper it. It can easily be seen, that by this method of heating there is no chance for oxidization, for the material while heating does not come in contact with the air. Another valuable feature in this method of annealing is that all parts are subject to the same amount of heat at all times. Before putting the material to be hardened in the liquid bath it is necessary to place it in a small oven above the furnace or near the bath so as to heat it slightly, because the immersing of the cold steel in the hot bath would strain it.



Sectional Elevation of Furnace



Method of Starting Furnace

In working around the furnace care must be taken not to allow the material that is being heated to come in contact with the electrode, nor must any water be permitted to fall into the bath. The time required to heat up a piece of steel is exceedingly short, being longer, of course, for large heavy pieces.

The bath for hardening or annealing completely fills the crucible, and usually consists of properly proportioned parts of barium chloride and potassium chloride, the correct portion of either depending upon the material to be hardened. For ordinary good steel the Schenectady factory is using a bath of 50 per cent. barium chloride and 50 per cent. potassium chloride, the amount of either being varied for raising or lowering the temperature. The more pure barium chloride they use, the higher the temperature, and the more potassium chloride used the lower the temperature. For this class of steel a temperature of about 850 degrees Centigrade is required.

For high speed steel where a very high temperature is required (about 1350 degrees

Centigrade), the bath consists only of pure barium chloride.

For temperatures below 700 degrees Centigrade prue sodium nitrate is used, and sometimes a mixture of sodium nitrate with potassium chloride.

In addition to hardening, the furnace may be used for softening tempered steel. For this process the liquid bath is kept at a temperature of about 250 degrees Centigrade. As in hardening, this method is far superior to the oil bath, because of the careful temperature regulation obtainable, which allows the tempering colors to appear gradually.

One of the most advantageous features, in addition to the high efficiency of the electric furnace as compared with the gas furnace, is the low cost of operation, as is shown by a test recently completed. The test was made by placing one hundred milling cutters in an American gas furnace, and a like number in the electric furnace. Each milling cutter had an external diameter of approximately 4.2 inches and a length of 5½ inches.

The electric furnace was of such design that only one milling cutter could be put into the bath at a time, whereas the gas furnace could accommodate two or three cutters at once. The reason that a larger number of cutters were not placed in the gas furnace at one time, was because they required careful attention to prevent burning the sharp edges. The result of this test is shown in the following tables:

Gas Furnace

Time required 50 hours	
Gas consumption 12355 cubic feet	$10.30
Motor power for air blast	1.20
Wages for 50 hours	8.40
Total	$19.90

Electric Furnace

Time required 10 hours	
Cost of current for 200 kw. hrs.	$4.80
Coke for warming before dipping into hot bath	.24
Extra salt for the bath	.13
Wages for 10 hours	1.68
Total	$6.85

These figures show without further argument the advantage of the electric furnace, not only in the matter of cost, but also in time required. Another point in favor of this apparatus shown by this test was that the quality of steel was much better.

Upon further comparison of the electric furnace with the more common lead bath or cyanide process, the former will be found very much more efficient, from the fact that the metallic salts of the electric bath have no effect on the composition of the steel, and the operator never comes in contact with dangerous fumes, such as are given off by the cyanide bath. One of the most valuable attributes of the electric furnace is the fact that there is practically no danger from fire, inasmuch as its outer walls are never hot; in fact, when the bath has a temperature of 1300 degrees Centigrade, the hand can be placed on the outside of the furnace without being burned. A still further consideration is that the cooling bath may be placed close to the furnace, thus reducing to a minimum the time required to remove the material from the furnace and cool it.

To sum up, it can be safely stated that in meeting the following practical requirements for tempering, the electric furnace has no equal.

First. It is necessary to be able to produce the correct temperature for any class of steel, and maintain this temperature indefinitely.

Second. It is often desirable to know the temperature of the steel in its heated condition.

Third. The material to be tempered must be heated equally and evenly, thus preventing any possibility of strains. Overheating often burns off sharp edges and points.

Fourth. During the time the material is being heated every precaution must be taken to avoid foreign matter entering the bath, otherwise the percentage of carbon might be altered.

Fifth. All pieces of the apparatus used in the process must be placed as near each other as possible, so as to increase the efficiency.

Sixth. An outfit is desired that can be easily handled by an ordinary workman.

Seventh. It is always necessary to have a furnace that requires very little care and attention.

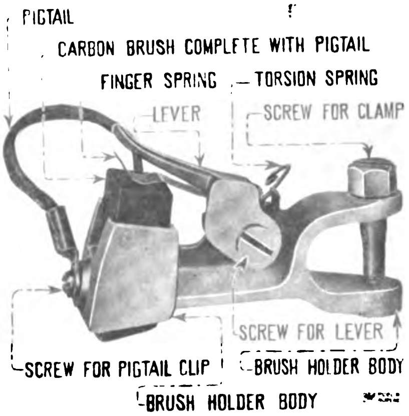
This class of furnace, due to its high efficiency and its ability to anneal finished articles and leave them looking nearly as bright as when they leave the emery wheel, is bound to replace almost every other type of furnace that is called upon to meet the requirements in the tempering of dies and other steel parts used in the manufacture of the following: machine tools, automobiles, razors, knives, fire arms, files, jewelry, fine instruments, all classes of steel, chisels, twist drills, torpedo shell points, etc.

The electric furnace operates most successfully from a single phase alternating current circuit, but can be designed for either two or three phase circuits. Under these conditions, however, it is difficult to design suitable regulating apparatus. Due to possible electrolytic effects it is not desirable to use the furnace on direct current circuits.

L-3 BRUSH HOLDER

By Edward Mink

Poor operation of D.C. motors is not infrequently due to faulty or improperly constructed brush holders. The essential features which should be embodied in a satisfactory and dependable brush holder are: simplicity, ease of adjustment, freedom of moving parts, etc. The L-3 brush holder, manufactured by the General Electric Co., and used on their CQ and CR motors, is a striking example of a simple, efficient and thoroughly reliable brush holder. This holder possesses certain novel and useful features which should place it in advance of any other brush holder now on the market. That part of the body of the holder which acts as a support, is forked and held firmly in place on the stud by means of a tapered screw. This method of support permits the ready removal or assembly of the holder without disturbing any other part of the machine, a feature which should certainly receive some recognition.



L-3 Brush Holder. Assembled

The construction and mounting of the lever with its auxiliary spring constitutes probably the greatest advancement yet made towards perfect smoothness and uniformity of operation. The small irregularities which may be present on the commutator surface are taken care of by the auxiliary spring, which, on account of its low inertia, responds very quickly to these; while irregularities of greater magnitude are cared for by the main lever. This main lever, which supports the adjusting spiral spring, is in turn supported by a carefully machined screw, about which the lever is free to turn. By placing the spiral spring arm into any one of the grooves cut into the brush holder body, a range of brush pressure sufficient for all commercial needs can readily be obtained.

Parts of L-3 Brush Holder

The guide boxes for the brushes are carefully broached, allowing the brushes to slip up and down freely, but without undue play.

The brush pigtails, which are very flexible, are firmly fastened to the brush holder body in such a position as not to interfere with the action of the lever arm, and yet allow perfect freedom of action to the brush.

The most favorable testimonial which could be presented attesting to the good qualities of this holder, is the list of complaints which have been satisfactorily adjusted by the substitution of the L-3 holder for holders of inferior design.

TYPE I AMMETERS AND VOLTMETERS

By D. P. Burleigh

General Electric Type I alternating current instruments are constructed on the induction principle and are of the round pattern switchboard type. They have exceptionally long and legible scales for instruments of their size, which feature facilitates the reading of the deflections and renders the instruments preferable for certain classes of work.

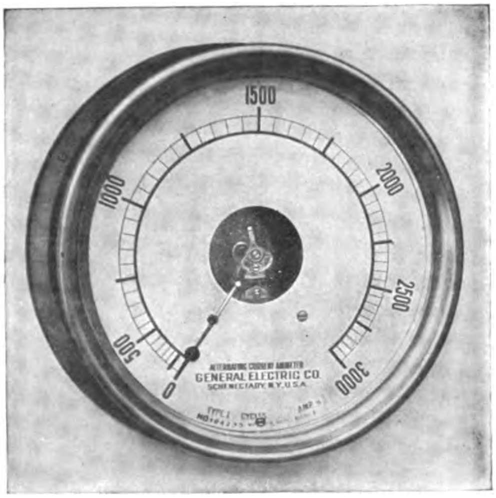


Fig. 1. Type I Ammeter

The instrument windings are mounted on a set of laminated iron punchings, the unit thus formed being placed in a round cast-iron case approximately 9 in. in diameter. The finish of the instruments is a dull black with copper trimmings.

The moving element consists of a spiral shaped aluminum disc and pointer mounted on a steel shaft, and so pivoted in jewelled bearings that the disc is free to move in the air gap of the set of iron punchings and between the poles of a permanent magnet. The current passing through the field coils creates in the iron core a magnetic flux which passes through this disc.

A turning moment, or torque, is obtained by placing a short circuited copper winding around one-half of each pole. This winding produces the same effect as the copper strip on a shaded pole induction motor. The movement of the needle is opposed by a phosphor bronze spring, so constructed as to retain its strength indefinitely. The indications of the pointer are rendered perfectly dead beat by the eddy currents set up in the disc as it passes between the jaws of the permanent magnet.

The iron case in which the moving element is enclosed protects the instrument from the influence of stray fields. The scale subtends an arc of 300 degrees, and is divided practically uniformly throughout. This feature is rendered possible by the spiral construction of the aluminum disc.

In order to reduce to a minimum the errors incident to ammeters of this construction, an internal shunt is placed across the current coils, as shown in Fig. 2. The combination of the two circuits, one highly inductive and the other practically non-inductive, produces the required compensation. In the case of frequency variation, the action is as follows: when the frequency decreases, the tendency of the torque to decrease is overcome by the increased magnitude of the current which flows through the winding; when the frequency increases, the action is the reverse; in either case the needle does not change its position.

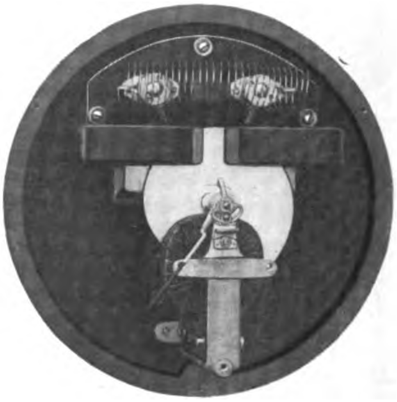


Fig. 2. Type I Ammeter Removed from Case

To compensate for temperature errors due to change in resistance of the aluminum disc, the shunt above described is made of a metal the resistance of which varies with the temperature. With a rise in temperature, the resistance of the disc increases, tending to diminish the resultant torque; but at the same time the drop across the shunt increases, forcing more current through the winding, and thus maintaining the torque constant.

The Type I voltmeters are of the same mechanical construction as the ammeters, except that no shunt is used.

Ammeters are made self-contained for capacities up to and including 200 amperes. For currents above 200 amperes, and for voltages exceeding 1150 volts, a 5 ampere instrument is furnished, with standard current transformer.

Voltmeters are made in capacities of from 50 to 750 volts, and each instrument is supplied with an external resistance box.

TRANSFORMER MAGNETIZING CURRENTS

The question of the effect of exciting current in transformers has until recent years been given but very little consideration. The limitations of design have been along the lines of heating and losses; maximum core densities have therefore been comparatively low, and low exciting currents followed naturally. While values up to 15 per cent. exciting current for induction motors have always been standard practice and have caused no unfavorable comment, that of transformers has generally been in the vicinity of 3 to 5 per cent.

The introduction of material for transformer cores that has a loss per pound much lower than the previous standard material has brought about a change in the limitation of design. With such material it becomes advisable in many cases to increase core densities and the question of proper limitations of exciting current demands consideration.

An increase in this value is perhaps naturally looked upon with suspicion if not with apprehension by central station managers; and in fact some general statements have appeared recently in the technical press which would tend to increase such suspicions if not carefully considered.

The following statement has been prepared to show the actual effect of various values of magnetizing current in the transformer on transmission and distribution systems. From these tabulations it will be observed that magnetizing currents up to 10 or 15 per cent., with as low as $\frac{1}{10}$ load, do not give very bad results, and that higher values could readily be allowed under certain conditions.

The following statements are all on the basis of normal voltage and frequency. The effect of an increase in voltage depends, of course, principally on the core density. Within good design limits an increase of 10 per cent. in voltage should not increase a normal voltage exciting current of 10 per cent. to more than 20 per cent.

It should be remembered that the exciting current of a transformer is made up of two components, namely: the energy component in phase with the e.m.f., which represents the power necessary to supply the transformer core loss; and a component in quadrature with the e.m.f., which is known as the magnetizing current and which is wattless with the exception of a small I^2R loss. This magnetizing current therefore does not represent energy and consequently has practically no effect on the transformer's efficiency. This current also has very little influence on the value of the total current in the transformer when it is operating at full load, but as the load decreases the effect of magnetizing current becomes more prominent until at no load it is most noticeable.

As an illustration, assume a transformer having a magnetizing current of 20 per cent. full load current. The energy current due to core loss being so small that it may be neglected, we then have at full load a primary current of approximately 102 per cent. rated primary current, the secondary current being normal. At no load the secondary current becomes zero and the primary current 20 per cent. of rated full load current. It will be noted from these results that this condition at full load will make very little change in the transformer's efficiency, its only effect being that of increasing I^2R losses 2 per cent., assuming the primary and secondary losses to be equal. Magnetizing current in a transformer has the same effect on an electric system as magnetizing current taken by an induction motor, and can be readily compensated for by the use of suitable capacity in the system. Induction motors are generally considered satisfactory if the exciting current at rated voltage does not exceed 15 per cent., and consequently a transformer having an average exciting current of 10 per cent. should not be considered detrimental to the system.

As previously stated, the energy current indicated by measurement of transformer core loss is very small as compared to the magnetizing current. It should be borne in mind, however, that the exciting current applied to a transformer equals:-

$$\sqrt{(\text{magnetizing cur.})^2 + \left(\frac{\text{core loss watts}}{\text{volts}}\right)^2}$$

If then a transformer is so designed as to reduce the core loss, with the exciting current remaining constant, it is evident that to satisfy the above equation the magnetizing current must be increased. This will, of course, result in a transformer of lower power factor; but as it has the same exciting current as the other one, and has at the same time a lower energy component, which is the only one consuming power, there is not the least doubt as to its being a more desirable transformer. Carrying out this same reasoning to a greater extent, it is evident that we may increase the exciting current over what was generally obtained in using transformers the cores of which were made up of iron not containing silicon, without in any way decreasing the efficiency of the system.

Since, in the above expression for exciting current, the second term under the radical is only about one per cent. of full load current, we may for convenience neglect it when considering high magnetizing currents, and still not affect appreciably the accuracy of results. We have for convenience, therefore, in the following tables, considered the exciting current to consist entirely of magnetizing current and assumed the primary energy current at full load as 100 per cent.

TABLE I

Primary current in per cent. of full load current, at different per cent. magnetizing current, for different non-inductive loads on the transformer.

Prim. cur. $= \sqrt{(\text{prim. load cur.})^2 + (\text{mag. cur.})^2}$

Per Cent Mag. Cur.	Per Cent Load					
	150	100	50	25	0	10
	Total Primary Current (Per Cent)					
0	150	100	50	25	0	10
2.5	150.02	100.03	50.06	25.12	2.5	10.3
5	150.1	100.12	50.2	25.5	5	11.2
10	150.3	100.5	51.0	26.9	10	14.1
15	150.7	101.12	52.2	29.1	15	18.0
20	151.3	102.00	53.9	32.0	20	22.4
25	152.1	103.12	55.9	35.3	25	26.9

TABLE II

Primary current in per cent. of full load current, at different per cent. magnetizing current, for loads of different power factors on the transformer.

Primary current $= \sqrt{(\text{prim. energy cur.})^2 + (\text{wattless load cur. + mag. cur.})^2}$

Per Cent Mag. Cur.	Power Factor of Load			
	100	90	80	70
	Total Primary Current (Per Cent)			
0	100	100	100	100
2.5	100.03	101.2	101.5	101.7
5	100.12	102.3	103.0	103.1
10	100.5	104.8	106.4	106.8
15	101.12	107.5	109.6	110.7
20	102.0	110.3	113.2	114.7
25	103.12	113.2	116.7	118.7

TABLE III

Effect of different per cent. magnetizing currents on the line power factor, for loads of different power factors on the transformer.

Per Cent Mag. Cur.	Power Factor of Load			
	100	90	80	70
	Line Power Factor			
0	100	90	80	70
2.5	100	89.0	78.8	68.9
5	99.9	88.0	77.7	67.8
10	99.5	86.0	75.2	65.5
15	98.8	83.7	73.0	63.3
20	98.0	81.5	70.6	61.0
25	97.0	79.3	68.6	59.0

TABLE IV

The effect of magnetizing current on the regulation of a transformer having 1 per cent. IR drop and different percentages reactance when carrying non-inductive load.

Primary volts $E =$

$$\sqrt{(100 + IR + WIX)^2 + (IX)^2}$$

Per Cent Mag. Cur.	Per Cent Reactance Drop			
	1	2	3	4
	Per Cent Regulation Drop			
0	1	1	1	1
2.5	1.025	1.05	1.075	1.10
5	1.05	1.1	1.15	1.20
10	1.10	1.2	1.30	1.40
15	1.15	1.3	1.45	1.60
20	1.20	1.4	1.60	1.80
25	1.25	1.5	1.75	2.00

TABLE V

The effect of magnetizing current on the regulation of a transformer having 1 per cent. *IR* drop and different percentages reactance when carrying an inductive load of 80 per cent. power factor.

$$E = \sqrt{(100 + PIR + WIX)^2 + (PIX - WIR)^2}$$

Example:—When transformer is carrying 10 per cent. magnetizing current and has a reactance of 2 per cent., then

$$E^2 = (100 + 0.80 \times 1 + 0.7 \times 2)^2 + (0.80 \times 2 - 0.7 \times 1)^2$$

$$E = 102.2 + \text{quadrature drop.}$$

The quadrature drop is $0.80 \times 2 + 0.7 \times 1 = 2.3$, which adds to the regulation 0.02, and which for convenience can be neglected as it is very small.

Per Cent Mag. Cur.	Per Cent Reactance			
	1	2	3	4
	Per Cent Regulation Drop			
0	1.4	2.00	2.60	3.20
5	1.45	2.10	2.75	3.4
10	1.50	2.20	2.90	3.6
15	1.55	2.30	3.05	3.8
20	1.60	2.40	3.20	4.00
25	1.65	2.50	3.35	4.20

TABLE VI

I^2R loss due to magnetizing current in per cent. of full load and full load efficiencies for these conditions.

Core Loss 1%
I^2R Loss 1%

Per Cent Mag. Cur.	Per Cent I^2R Loss Due to Mag. Cur.	Full Load Efficiency
0	.0	98.040
5	.0025	98.038
10	.0100	98.031
15	.0225	98.019
20	.0400	98.002
25	.0625	97.980

AN ELECTRICALLY DRIVEN BREWERY

By C. A. RAYMOND

The George H. Glennon Brewery, located at Pittston, Pa., has recently been equipped throughout with electric drive. The brewery is thoroughly modern in every respect, and is one of the foremost in this section of the country. The motors throughout the plant are of General Electric make, and have given entire satisfaction.

Cooker; Driven by General Electric CQ 15 h.p. Totally Enclosed Back-geared Motor

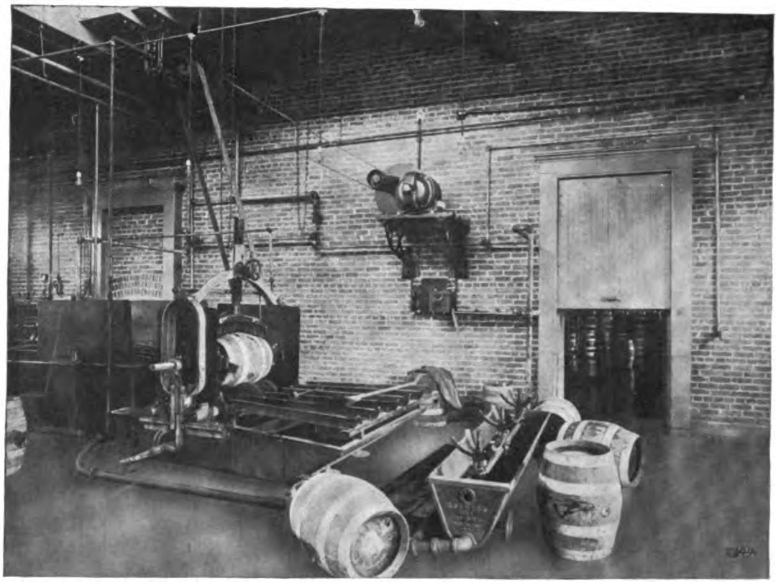
In building this brewery, everything was arranged for the best and most modern practice, involving what is termed the "gravity plan." By this is meant that in each department the raw materials and beer are elevated but once to the highest point in the building, whence, in progress from one stage of manufacture to the next, they fall or flow from floor to floor by gravity.

It is obvious that a vast saving in both power and labor will accrue from the continuity of operation obtained through this method of manufacture. It is claimed that for an equal yearly output the cost of operation in older plants of poor design or faulty arrangement is as much as double that of the plant under discussion.

The process of brewing, as carried on at the Glennon brewery is given below.

The plant is divided into three departments; viz., the elevator or mill house, the brew house, and the cellars. Each department is operated on a separate gravity plan for the transfer of materials. In the first department (the elevator or mill house), the grain is taken from a car and dumped into a hopper leading to the basement, where it is caught up by an endless belt-bucket conveyor and carried to the storage bin or hopper on the top floor of the building. The conveyor is operated by a 7½ h.p. back-geared motor, as slow speed (about 35 r.p.m.) is required on the driven shaft. The malt then passes through a slide in the bin and drops into a scale hopper, where the desired quantity is weighed out; then through the screening reel into the malt mill, where it is crushed for the mash. One 7½ h.p. direct connected motor drives a blower for dusting the grain and carrying off the chaff from the rolling screen. The malt mill is operated by a 10 h.p. motor at 500 r.p.m., and has two smooth rollers, one of which is driven by the motor, while the other follows due to the friction of the grain between the two. Before the malt drops between the crushing rollers it has to pass over a series of permanent magnets, which catch and remove any tacks, nails, or particles of iron that might damage the roller surfaces. The prepared malt now passes to the basement and is again carried to the top of the building by the same conveyor that elevated it in its original state; but this time, instead of going to the same storage bin as before, it is taken by another conveyor to the storage bins in the second department, having now both completed the first gravity stage and finished with the first department.

The second department consists of the brew house. Here the crushed malt is deposited in two hoppers on the top floor by a belt conveyor operated by a 5 h.p. back-geared motor, giving a speed of about 35 r.p.m. on the driven shaft. With these hoppers the second gravity stage begins. Besides the malt, raw cereals—rice and corn grits—are elevated in sacks and stored for use as needed.



Keg and Barrel Washer; Driven by Gen. Elec. CQ 7½ h.p. Totally Enclosed Back-geared Motor

To form the cereal mash, the raw cereals and *part* of the crushed malt from the hoppers are weighed out in certain definite proportions and dropped into the cooker, together with water from a cold water tank. The cooker or converter is a cylindrical vessel made of iron and provided with a stirring device consisting of a central vertical shaft with radiating stirring arms placed in a spiral position one above another. These arms revolve at about 18 r.p.m., the shaft being driven, through a system of gears, by a 15 h.p. back-geared motor mounted on top of the converter. Steam is now applied to this mash, and due to certain temperature conditions and agitation, a chemical change takes place; and when the mass is properly gelatinized it descends through openings to the mash tub on the floor below. As the cereal mash drops into the mash tub, the remaining crushed malt in the hoppers is added, together with the proper quantity of water from the tanks.

The mash tub is used for extracting the valuable ingredients from the malt and cereals and further converting them into products desirable for brewing; it consists of a cylindrical vessel made of iron and supplied with a removable perforated bronze strainer, or false bottom, placed above the real bottom. The tub is further supplied with a stirring device for mixing the materials with water, a steam jacket for heating, and a sprinkler for supplying a spray of water to wash the grains. The stirring device is not only turned by the central vertical shaft, but has revolving paddles that keep the mash well mixed and the temperature uniform. The shaft is operated at about 10 r.p.m., and is driven through a system of gears by a 20 h.p. back-geared motor. This is mounted on the floor directly under the mash tub. A nonrevolving shovel, located just above the false bottom, is used for throwing out the grain after the mash is finished and the wort or extract run off. The term "wort" is applied to the liquid obtained from the raw materials by the process of brewing proper, before it is transformed into beer by fermentation; in other words, it is the extract formed by the water in passing through the grain. Connected to the bottom of the mash tub is a series of copper tubes which convey the wort to a horizontal cylindrical copper vessel, called the grant, from which it is pumped back to the mash tub or run into the kettle. After the wort is drawn off, there is no further use for the grain; it is therefore emptied into a tank, and after being drained off, is sold principally for cattle feed.

The kettle is the vessel in which the wort is boiled, for the purpose of precipitating the albuminoids, for extracting the bitters and oil from the hops, which are added at this time, and for concentrating the wort. The kettle is built entirely of copper, is pear shaped, has a hood to carry off the vapors, and a double bottom for a steam jacket. When the wort is thoroughly boiled and in proper condition it is put into the hop jacket, which strains out the hops contained in the wort after it leaves the kettle. It is next pumped from the hop jacket to the cellars, thus completing the second department.

The wort is received at the highest point in the cellars; namely, the surface cooler or beer tank. From this point it begins the third gravity stage, descending by successive steps over the Boudelot cooler into the settling tubs, thence into the fermenting tubs and storage tanks, and finally into the chip casks, from which it is racked off into trade packages.

About sixty days are required for the beer to go through the third department, when it is ready for the trade. In this section of the brewery a motor is installed for driving the chip washer, and another for operating a small beer pump used for transferring beer from one tank to another. The chips are put into the beer during one of the last stages of the process, to take up the yeast germs. After the beer is drawn off, the chips are washed and used again.

The capacity of the brewery is 60,000 barrels per year.

AN ELECTRIC MOTOR IN A GRIST MILL

By Edward L. Cooley

In the town of Houlton, Maine, a number of farmers and others interested in agriculture have formed a co-operative society called the "Houlton Grange". This society is an incorporated body and does a general business in groceries, flour, seeds, hardware, etc., selling only to its members. The sales for 1907 amounted to over $100,000.

The Grange has recently enlarged its building to include a grist mill, which has a storage capacity of about fifteen cars of corn and twenty cars of feed. The building is centrally located and very well arranged both for storing and handling the material, and also for the convenience of its members. One end of the building contains a driveway large enough to accommodate a two-horse team, with opposite doors for the entrance and exit of the wagons bringing the grain. The team is thus protected from the weather while discharging and receiving the load. The hoppers for receiving the grain are alongside this driveway, three conveyors carrying the grain to the proper bins for storage. At present there is installed one 18 in. grinding mill and three elevators, all operated by one 20 h.p., three-phase General Electric motor. The capacity of the mill averages a bushel a minute, varying with the material being ground.

When the matter of power for operating the mill was being decided, steam and gasoline engines were both considered, but were rejected in favor of the electric motor, owing to the small space required by the motor, the convenience in starting, cleanliness, absence of noise, and economy of operation. Furthermore, the absence of heat—a very objectionable element in a mill—is assured, and the danger in winter of freezing of the water required by both the steam boiler and gasoline engine is also done away with.

The members of the Grange are more than enthusiastic about the successful operation of the electric motor. The grist is handled so rapidly that the farmer is able to deliver his raw material and drive away with the finished product after waiting a comparatively short time; whereas, formerly, when mills were operated by water power, frequently in inaccessible localities, they were required to make two trips.

NOTE

Through a mistake, the curve of adiabatic expansion was omitted from Fig. 1 in the article on The Low Pressure Steam Turbine, appearing in the November Review (page 225). While this curve was mentioned, it was not discussed, the author confining himself to the isothermal curve. The two curves correspond very closely, the relative values of their ordinates being as follows:

Abscissæ	Ordinates	
	Isothermal	Abiabatic
1	120	120
2	60	54.6
4	30	24.9
8	15	11.3
16	7.5	5.16
32	3.75	2.35
64	1.87	1.07
128	.94	.45

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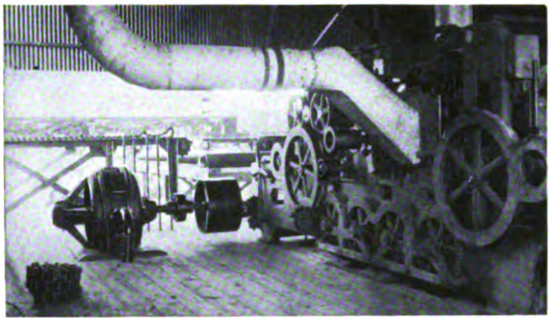
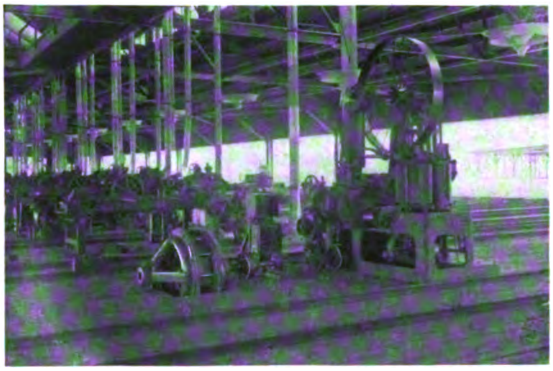


GENERAL ELECTRIC MOTOR DRIVING A TIMBER SIZER



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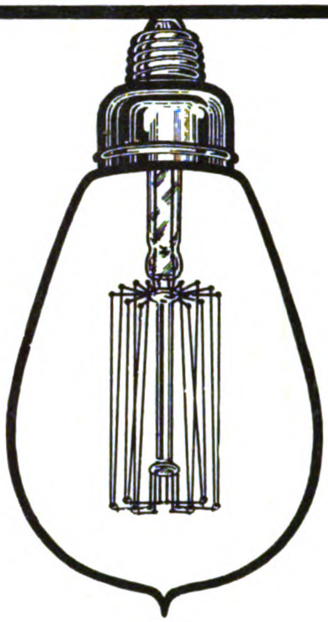

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